Microlearning with Mobile Devices:

Effects of Distributed Presentation Learning and the Testing Effect on Mobile Devices

by

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ABSTRACT

This study investigated the effects of distributed presentation microlearning and the testing effect on mobile devices and student attitudes about the use of mobile devices for learning in higher education. For this study, a mobile device is considered a smartphone. All communication, content, and testing were completed remotely through participants' mobile devices.

The study consisted of four conditions: (a) an attitudinal and demographic pre-survey, (b) five mobile instructional modules, (c) mobile quizzes, and (d) an attitudinal post-survey. A total of 311 participants in higher education were enrolled in the study. One hundred thirty-seven participants completed all four conditions of the study. Participants were randomly assigned to experimental conditions in a 2 x 2 factorial design. The levels of the first factor, distribution of instructional content, were: once-per-day and once-per-week. The levels of the second factor, testing, were: a quiz after each module plus a comprehensive quiz and a single comprehensive quiz after all instruction. The dependent variable was learning outcomes in the form of quiz-score results. Attitudinal survey results were analyzed using Principal Axis Factoring to reveal three components, (a) student perceptions about the use of mobile devices in education, (b) student perceptions about instructors' beliefs for mobile devices for learning, and (c) student perceptions about the use of mobile devices post-instruction.

The results revealed several findings. There was no significant effect for type of delivery of instruction in a one-way ANOVA. There was a significant effect for testing in a one-way ANOVA There were no main effects of delivery and testing in a 2 x 2 factorial design and there was no main interaction effect, and there was a significant effect of

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testing on final quiz scores controlling for technical beliefs in a 2 x 2 ANCOVA. The significant difference in testing was contradictory to some literature.

Ownership of personal mobile devices in persons aged 18–29 is practically all-inclusive. Thus, future research on student attitudes and the implementation of personal smartphones for microlearning and testing is still needed to develop and integrate mobile-ready content for higher education.

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CHAPTER 1

INTRODUCTION

Learning anywhere at any time is not a new concept. Books have been available

for centuries and were probably the first "mobile" learning device. In his introduction to

The New Landscape of Mobile Learning, Searson (2014) wrote: "Consider for a moment,

the book as education's first mobile device; specifically, the type of book driven by the

invention of Johannes Gutenberg's printing press." What is new in the concept of mobile

learning is access to interactive learning content, contact and communication with

teachers and other students, and assessments through the internet via wireless-enabled

smartphones.

Students have long carried backpacks full of books to-and-from class lugging

them around like a sack of bricks. Textbooks provided the opportunity to catch up on

reading assignments or other instructional support, but could not provide testing,

feedback or interactive engagement. Today's students now connect with information in a

vastly different way. The Pew Institute (2017) found that 95% of Americans own a

cellphone of any kind and among adults between the ages of 18–29 virtually 100%

owned a cellphone of any kind, with 92% owning a smartphone.

The first phone with a keyboard was developed in 1997, and in 2007 Apple

released the first iPhone with a multi-touch surface and virtual keyboard. 1n 2007,

Americans sent more text messages per month than received phone calls. Our mobile

society quickly embraced 160-character text messages, one-minute or shorter video

content, and apps (applications) capable of providing e-reading, educational support,

interactive games, lists, notes, and reminders. Today a student traveling by shuttle

between campuses or relaxing on a campus mall is connected to information and learning resources previously unimagined. The learning content can be multimedia learning pushed to students by instructors, content that includes instruction and links to additional resources, assessments linked to course records, assessments that provide feedback, and content with embedded opportunities to communicate with instructors and other students. The possibilities are endless.

Now consider a student working on short-lesson modules, perhaps three-to-five minutes in length while taking the shuttle. Each module includes discrete instruction and assessment. The modules are short enough to be consumed in a single setting but complete enough to address a specific teachable concept. One entire lesson plan for the week might include 10 or more modules to complete a section or learning objective. Alternatively, a module might provide flipped classroom support to prepare students for the day's learning activities. Embedded in the module is an assessment that when completed is sent directly to the course database to be graded thereby satisfying the need for documented grading and feedback about student academic success.

Importance of the Problem

Adoption of mobile devices for personal use is virtually comprehensive in society, but opportunities in education are still struggling to catch up. Chen and deNoyelles (2013) indicated that in a study about mobile-device usage, more than half of college students utilized a mobile device for academic purposes. Eighty-two percent of students that owned a tablet device reported using the device for academic purposes while only 58% of students that owned a smartphone used their device for academic purposes. The study also indicated that there was a negative relationship between students' GPA and

academic use of smartphones and that freshman used smartphones and small mobile devices in an academic setting more than juniors or seniors. Students also expected technological support from instructors, but only about 54% of students indicated that their instructors provided support (Chen & Denoyelles, 2013).

The foundation for the content in this study was based on a multimedia, animated instructional learning study about how lightning works developed by Johnson and Mayer (2010). The original materials were created and tested by Mayer, Heiser, and Lonn (2001) and later revised (Johnson & Mayer, 2010). Both studies used 16 segments of narrated animation in a 140-second presentation. The instruments and content in these studies (Mayer et al., 2001; Johnson et al., 2010) were not extensive enough to be used as the entire foundation for this research study but provided an outline for the instructional content. The content was expanded and includes resources from: the National Oceanic and Atmospheric Association (NOAA), and the National Weather Service, and Theweatherprediction.com.

This study was designed to examine a hypothetical learning situation in which the concept of mobile learning and assessment can be evaluated and tested. The next section provides a literature review of distributed presentation learning, pacing, and the testing effect and explores potential gaps in knowledge about these topics. Some areas are grounded in more than 100 years of research. It is not possible to cover all the research for these topics in this paper. A brief historical presentation of each topic is followed by a description of recent research articles and their significance to the study. A literature review of microlearning, mobile learning, and human interactions with mobile devices is

also presented to relate the historical concepts in a contemporary environment and provide a foundation for this study.

Overview of the Study and Research Questions

The purpose of this study was to investigate outcomes of mobile learning, distributed presentation, and testing on mobile devices. Specifically, the study investigated differences between distributed presentation microlearning outcomes based upon time of evaluation after microlearning instruction and whether planned – once-daily instruction and testing or massed availability of instruction and testing has an impact on learning outcomes. Additionally, this study examined pre- and post-instruction student attitudes about microlearning, mobile devices and mobile use in academic settings. The research questions for this study are:

1. Is there a difference in learning outcomes depending upon the method of delivery of instruction – distributed presentation or massed availability?

2. Is there an improvement in learning outcomes with the testing effect on mobile devices depending on the number of assessments after instruction?

3. What are students' attitudes about using personal mobile devices for learning?

4. What are students' beliefs about the ease of learning on mobile devices?

The study employed a 2 x 2 factorial design and compared differences in learning outcomes based on type of instructional presentation and time of delivery of assessment. The two independent variables manipulated in this study were distribution of presentation of instruction, with two levels once-per-day or massed availability in which all instruction was made presented without restriction to availability, and testing with two

levels – immediately upon completion of instruction or at the end of all instruction. The dependent variable was learning outcomes in the form of scores on the comprehensive quiz. Participant attitudes about learning on mobile devices were evaluated as co-variates to the dependent variable and as attitudinal exploratory factor analysis.

Limitations of the Study

This study was conducted entirely online, through the Arizona State University Blackboard Learning Management System (LMS) version 9.1, Google documents (docs), forms and sheets, and email. Students were expected to participate in the study with the same academic integrity and rigor outlined in the Arizona State University Student Code of Conduct. At the beginning of the instructional and assessment components, students were asked to sign a digital acknowledgment of integrity and not to use resources other than the instructional material, such as Google or the internet. Unfortunately, there was no way to prevent participants from not adhering to the guidelines, and in at least one example a participant responded with text revealed to have been copied verbatim from the National Oceanic and Atmospheric Association's website.

The Blackboard LMS employed by Arizona State University during this study was Blackboard version 9.1. To access content via a smartphone, participants had to download the Blackboard app available through Google Play for Android devices and iTunes for Apple iOS devices. The app was upgraded in 2016 to improve the responsiveness of the interface on small devices such as smartphones. An outage of the entire Blackboard system was experienced one Monday for approximately six hours. Participants in the daily distribution of instruction were moved to the following week. Participants in the massed instruction were not moved. Some technical issues arose for a

few participants. However, most were resolved through reference to an online instruction sheet, screen captures shared through Google Docs and email.

Another limitation of the study was the high dropout rate. More than 430 potential participants signed the participation consent form and were enrolled in the study. Of those 301 completed the pre-survey, only 137 fully completed the instructional content, and only 97 completed all three phases of the study that is pre-survey, instruction, and post-survey.

CHAPTER 2

LITERATURE REVIEW

Learning anywhere at any time is not a new concept, but mobile devices bring new opportunities to learning as briefly discussed in the Introduction. Learning theory has more than a century's worth of research, but early research is the foundation of instructional design and still plays a significant role in today's learning environments. Some theories have become particularly relevant with the potential for learning on mobile devices.

The literature review presents a brief historical view of learning theories relevant to this study then associates those theories to current research and findings of distributed presentations and massed presentations, the testing effect, microlearning, and mobile learning or m-learning. The literature review also discusses new areas of study related to attitudes about learning on mobile devices and considerations for creating content unique to mobile devices.

Distributed Presentations

Spaced or distributed presentations (DP) are defined as practice or learning that is repeated and spaced over a period of time (Ebbinghaus, 1913). Massed presentations (MP) are defined as learning that is studied over a short period of time and are exemplified by traditional lectures in higher education where a large amount of information is provided in a single presentation. Research focusing on DP-MP has a long history. In 1885, Ebbinghaus found that spaced instruction and repetition of learning improved errorless recall. Since Ebbinghaus, there has been a substantial amount of research and literature to support this theory (Craik, F.I.M, 1970; Gates, 1917; Melton,

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1970). Many researchers conducted studies on remembering word lists, images or numbers. Early studies by Ebbinghaus and Peterson and Peterson (1959) relied on consonant-vowel pairs that had no meaning. Tulving (1967) and Hintzman and Block (1971) used lists of common nouns. This literature review will focus on select recent studies. The studies researched multimedia content and complex concepts that align more closely with potential learning on mobile devices. These studies are believed to be more relevant to the current state of distributed presentations in higher education.

To define learning experiments in the context of DP-MP studies, this portion of the literature review typically adheres to Tulving's (1967) description of a learning experiment. A learning experiment consists of two operationally distinguishable phases: input and output. During the input phase, a student is presented material for study while during the output phase the presented material is recalled and tested. These two phases are present in free-recall learning experiments where the number of combinations of input and output phases is systematically varied.

Peterson and Peterson (1959) conducted a series of studies about spacing and short-term retention that would serve as the foundation for many subsequent studies. In this series of studies Peterson and Peterson (1959) used individual items, that is, consonant syllables as opposed to the traditional use of lists, and found that participants would forget consonant syllable pairs as recall intervals increased. Additionally, they found that by using controlled rehearsal, a process in which the participants counted backward or used some other method to distract from practicing the syllable pairs, forgetting increased at different rates depending upon the amount of controlled rehearsal.

In a subsequent study, Peterson, Saltzman, Hillner, and Land (1962) studied retention of paired words in short-term memory experiments. The study found that immediately after presentations, participant recall was almost perfect and that after 2- and 4-sec. intervals retention was higher than after an 8-sec. interval. However, the effect reversed at the 16-sec. interval whereby after a second presentation of materials at 16-sec. retention was improved. This method is known as the Continuous Paired Associate (CPA) method. In a follow-up study, Peterson, Wampler, Kirkpatrick, and Saltzman (1963) performed a series of studies using a similar CPA method, but with varied lengths of spacing intervals to further research the spacing effect. They found that spacing presented material over increments of time increases the effectiveness of learning and remembering.

Fishman, Keller, and Atkinson (1968) noted that spacing of learning sessions had received significant experimental investigation and support but that questions related to optimal spacing had not been resolved. Fishman et al. described a hypothetical situation in which six days were available to learn a set of 24 spelling words. One solution was to select two sets of four words for presentation every other day over a period of six consecutive days, and the other solution was to present all six sets of four words on one day. Fishman et al. described these two conditions, respectively, as distributed and massed presentation, which they empirically tested in one of the earliest examples of testing with computer-assisted instruction. They found that the probability of a correct response during learning sessions was higher for the massed presentation than the distributed presentation, however, when retention tests were performed 10 and 20 days later, students in the distributed presentation had better retention.

Tulving (1967) studied free-recall learning experiments in which the number and sequential combinations of input and output stages were varied in an organized manner. The study focused on the effects of the recall tests. He found that the recall tests seemed to facilitate and interfere with the recall of items. This was counter to previously adopted views that the strength of items in a free-recall test experiment increase as a result of the number and reinforcement during input phase, and that the recall test simply provided an accounting of the degree of learning.

Melton (1970) discussed previous research about DP and MP and found that it pertained mostly to perceptual motor skills, verbal learning, and analytic tracking tasks. Melton noted that the study of rote learning tasks was easier to examine because it was not confounded by more complex learning such as trial-and-error learning and instrumental learning. Melton found that Peterson, Saltzman, Hillner, and Land's (1962) study broke with traditional list recall by using the CPA method. Melton's (1970) studies were influenced by Tulving's (1967) findings whereby DP and free-recall tests allow different cues to be stored than does massed presentation and that the cues improved retrieval. He summarized his findings by stating that the effects of DP on remembering have been studied and proven in enough experimental situations that there is basic understanding under which conditions repetition improves remembering.

Hintzman and Block (1971) performed studies on the effect of spacing and repetition on performance and discussed that repetitions may form independent traces upon memory and that these traces may be separate and discernable. They found that repetition increases and strengthens memory traces. In a subsequent study, Hintzman

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(1974) showed that two spaced presentations were almost twice as effective as a single mass presentation in improving achievement.

In a more recent study, Raaijmakers (2003) summarizes that in general, the spacing of presentations will lead to more contextual, structural, and descriptive components being stored in memory. Also, Braun and Ruben (1998) indicated that spacing instruction is of practical importance because it can be implemented without any additional study time or training. Although much research has been done to show that distributed presentation (DP) and spacing is more powerful for learning outcomes than massed presentation (MP), instruction in higher education tends to be a pervasively massed presentation in the style of three-hour long lectures and linear.

In a departure from using vocabulary, pictures and lists, Raman, M., Mclaughlin, K., Violato, C., Rostom, A., Allard, J., & Coderre, S. (2010) investigated distributed delivery learning (DD) as compared to massed delivery learning (MD) with gastroenterology residents. In this study, the authors use slightly different language to describe the instruction but the method is consistent with DP instruction and MP instruction previously mentioned. Most higher education and medical school instruction are based on multi-hour lectures; the goal was to determine if DD would be as effective or more effective than MD for acquiring learning that requires higher levels of reasoning. The one-week post-exam results for the DD groups were improved over that of the MD groups, and at three months a post-test showed that the DD group continued to score higher than the MD group. Ramen et. al. (2010) concluded that long-term nutrition knowledge was improved with distributed learning as compared to mass learning.

In a recent review of the literature, Son and Simon (2012) found that on the whole, spacing instruction leads to better performance than mass instruction. This performance advantage was evident in laboratory experiments, in the classroom, across all ages, and in all learning domains. Additionally, Son and Simon (2012) noted that there were only a few instances of massed presentation outperforming distributed presentation. They found that the instances and environments were relatively rare in real-world settings and concluded that for both educators and learners, spaced or distributed study is the best strategy.

This study will employ the independent variable – distributed presentation instruction. This variable has been widely researched. This study defines distributed presentation instruction as instruction that is spaced over a series of learning interventions and is a short duration of time – five to seven minutes or less.

Testing Effect

The testing effect also has been widely researched by Gates (1917), Whitten and Bjork (1977) and McDaniel and Fisher (1991) among others. As early as 1917, Gates studied outcomes of the testing effect and found that testing improves long-term memory and retrieval of information needed for future performance. The testing effect is defined as improved performance on learning when delayed retention and practice retention tests are implemented after studying material, as compared to studying the material twice.

In a frequently cited study, Whitten and Bjork (1977) investigated resting and retrieval where they reported that learning gained from retrieval practice produced results similar to practice and repetition. Additionally, successful retrieval increases memory in an equivalent method to repetition. The authors also discussed that in practical

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applications as learning may be optimized when retrieval practice is delayed for a brief interval and that the spacing-of-tests effect produces results that are qualitatively similar to the spacing-of-repetition. They concluded that successful retrieval supplements memory in a similar way as repetition.

McDaniel and Fisher (1991) performed experiments examining the influence of test taking and feedback in promoting learning and found the beneficial effects of testing whereby tested facts were better recalled on a final criterion-referenced test than untested facts. They also found that tested facts were also better recalled than facts that were presented for additional study or spaced instruction.

A series of experiments by Carrier and Pashler (1992) sought to extend research on the testing effect and found that after some amount of learning has been attained, learners should be engaged in forced retrievals (tests) without having access to the original instruction. Additionally, the authors found that in experiments in which performing a test trial/study trial (TTST) condition as compared to a strict study trial (ST) condition was conducted; the TTST condition led to better performance than the ST condition. Carrier and Pashler (1992) rejected the hypothesis that successful retrieval is beneficial only to the extent that it provides another study experience.

Recently, Roediger and Karpicke (2006) researched the testing effect under more educationally relevant conditions. Previously the testing effect focused on materials similar to materials used in the spacing effect – words, syllables, and images – but they used materials from the preparation book for the Test of English as a Foreign Language. Passages were selected and participants either restudied or were tested on the material. The study reported that the positive effects of repeated testing were dramatic where tested

students recalled 61% of materials after one week compared to repeated studying students recalled 40% of materials after one week.

In an another study, Karpicke and Roediger (2007) found that delaying an initial retrieval attempt, similar to equally spaced retrieval practice conditions, promotes long-term retention and learning by increasing the difficulty of retrieval on the first test and is consistent with prior research on the topic. The authors concluded that practicing retrieval is a robust method to enhance learning and retention, but that expanding retrieval may not be as effective as equally spaced practice and that the desired technique to enhance learning is a delayed initial retrieval attempt rather than expanding intervals between retrieval.

For most studies investigating the testing effect, the instructional materials involved verbal learning materials like word lists, prose passages, and in only a few cases, simple pictures as learning materials. Johnson and Mayer (2009) proposed a series of multimedia learning experiments that involved more complex materials, which included both words and pictures. In their experiments, Johnson and Mayer found that the testing effect can be obtained with multimedia lesson containing multiple modalities, words, and pictures. The authors sought to explore whether the testing effect would extend beyond simple retention test to transfer skills. Transfer skills are considered the ability to solve more conceptual problems such as troubleshooting, modifying or redesigning something to achieve a goal and diagnosing problems. They found that the testing effect can be obtained with transfer tests that contain educationally relevant items.

Wojcikowski and Kirk (2013) took testing effects experiments a step further and integrated detailed feedback into testing. The experiment tested high-level knowledge of

biomedical information with medical students. The experiment consisted of multiple-choice tests deployed through an online-testing system. The study found that compared to a test situation in which participants only received feedback about the correct answer, participants that received detailed feedback explaining why each answer was correct or incorrect, the detailed feedback group performed significantly better. Wojcikowski and Kirk found that test-enhanced learning with detailed feedback has the potential to reinforce student knowledge of the complex material.

This study will employ the independent variable – the testing effect. Though this variable has been widely studied, it has not been studied in mobile learning. This study defines the testing effect as improvement in learning outcomes through testing.

Distributed Presentation and Testing with Mobile Devices

As previously discussed, considerable research has been conducted on distributed presentation instruction and testing, but not much has been researched about distributed presentation instruction and testing on mobile devices. After years of trending toward parity, in 2014, the number of mobile device users overtook desktop users, including users of laptops. Pew Institute (2017) found that 95% of Americans own a cellphone of any kind with 77% owning a smartphone. Among adults between the ages of 18–29 virtually 100% owned a cellphone of any kind with 92% owning a smartphone. Younger adults and those with lower incomes and education are more dependent on smartphones to access the Internet. As smartphone usage increases so do the number of hours spent accessing the web and multimedia content. Bosomworth (2015) found that 2015 year-to-date Internet usage and engagement growth on mobile devices are also at the tipping point. Fifty-one percent of all digital media consumption is on mobile devices. However,

development of instruction and education on mobile devices significantly lag development of other forms of mobile content. For the purpose of this study, mobile devices are defined as personal smartphones with an advanced operating system combining the features of a personal computer and a cellphone and employing touchscreen interactivity. Mobile devices are Internet capable without the use of data cables or cords, lightweight, and portable.

Mobile learning is defined as the use of mobile technologies to promote and distribute learning. Traxler (2005) originally described mobile learning as any educational provision where the sole or dominant technologies are handhelds or palmtop devices. Later, Traxler (2010) revised his thinking about mobile learning to make it less technology centric and to include additional concepts of distance learning, and virtual and real spaces for learning. Recently, Allen and Seaman (2015) found that online, or distance education continues to grow and that more than one in four students (28%) are taking some type of distance education course and 72.7% of all undergraduate students in public institutions are participating in some type of distance education.

Educational institutions were early adopters of apps on mobile devices through the use of e-books and educational games. However, e-learning designed for desktop and laptop computers fails for effective learning on mobile devices. Alrasheedi and Capretz (2013) found that despite the immense penetration and worldwide popularity of the usage of mobile technology, its adoption in the education section, especially higher education, has been slow.

Prensky's (2001) assertion that digital natives (i.e., persons born after 1980) are more technically adept than digital immigrants, persons born before 1980, is being

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challenged. New research is finding that digital natives' use of technology in higher education may be more dependent on students' majors than simply their year of birth (Margaryan, Littlejohn, & Vojt, 2010). The scenario is slightly different or instructors. There was no significant difference in teachers' attitudes about mobile usage as support for education in classrooms for teachers less than 32 years of age and those between 33–49, for teachers over the age of 50, it varied significantly (O'Bannon & Thomas, 2014). Chen and deNoyelles (2013) found that instructors are unprepared to integrate mobile technologies in learning as most faculty professional development opportunities do not specifically focus on adoption and conversion of mobile learning into course content.

Another barrier to adoption of mobile learning is students may not be willing to use their personal mobile devices for nonsocial interactions. Most students prefer to keep their academic and social lives separate, and view social networks as more about connecting with friends and less about doing academic activities. E-mail is the preferred method of communication with instructors while on-demand interactive communication methods (i.e., texting, instant messaging, online chatting) are commonly used among students to interact with one another (Dahlstom, 2013).

Smartphones and mobile devices may not be ideal for consuming traditional e-learning, which includes online learning and distance learning generally taught through online videos and tutorials. Much e-learning consists of recorded classroom lectures of indeterminate length that lack interactivity. Recorded lectures can be difficult to update and edit, bandwidth intensive, and not responsive for viewing on smartphones and mobile devices that have smaller viewing ports than computers.

The multimedia and technology effect has been widely researched (Clark, 2001; Mayer, 2002) in an effort to distinguish media's influence on learning. Original studies focused on the use of computers, e-learning, and digital books and found that there was no evidence to support the idea that media influences learning (Clark and Feldon, 2005). As technology and devices improved and became more widely available, findings by Sung and Mayer (2013) indicated that in a multimedia lesson study comparing students using a computer vs. an iPad, a media effect between the two groups was observed ($d = .60$). The importance of effective instructional design strategies should not be diminished and are still necessary to improve learning outcomes across all media however, the addition of handheld devices may increase student engagement in learning. (Sung & Mayer, 2013).

Definition of Microlearning and Examples

Microlearning is a relatively new phrase and is described as learning that deals with relatively small learning units and short-term-focused activities (Hug, 2005). Rather than limit microlearning to a single definition, Hug stipulated that microlearning has certain characteristics. Microlearning is relatively short in duration, ranging from a second to up to an hour. It consists of small units of content such as limited amounts of text and narrow subject matter and takes on the form of fragments of knowledge. It is usually part of a larger curriculum or set of other instructional material. It can be situated or non-situated as well as sometimes repetitive and action-based. The foundations of microlearning can also be related to concepts of chunking (Miller, 1956) where information for processing and reduction of extraneous cognitive load is managed by parsing content into digestible units.

Job and Ogalo (2012) found that microlearning emerges from micro-content and micro-content is described as small learning units and short-term activities. Although the term microlearning may be new, micro-content and microlearning concepts are grounded in cognitive load theory (Sweller, 1988). In study for OPALESCE (Online Portal forand Active Learning System for Senior Citizens in Europe) Buetner and Pechuel (2017) designed "Micro Units" as a way to rethink the delivery of instruction for mobile learning. They defined Micro Units as:

> A Micro Unit is a very short learning course that focuses on one topic and has clear learning goals. An example of a Micro Unit could be "How to change your motor oil" which would be a rather practically oriented lesson or "The Battle of Waterloo" which would be a brief history lesson. Since Micro Units are meant to be short, generally not lasting more than 10 minutes, bigger topics can be grouped in suits of Micro Units. Micro Units consist of a number of "views" that can be seen in a certain order. A learner can go through the views one by one, stop at any time, and go back at any time. A view consists of one of eight content elements which can be categorized in four groups: Text Elements, Graphic Elements, Audio Elements and Video Elements.

Attitudes about use the of Personal Mobile Devices for Learning

Previous research indicated that although student ownership of mobile devices is high, attitudes about using personal mobile devices for learning in higher education was moderate (Chen et al., 2013; Sung et al., 2013). This may be changing. Newer research on the topic by Thomas and Muñoz (2016) indicates that 90.7% of high school students in an urban school district were using mobile phone features for school-related work and more than 70% believed that mobile phones could help support learning. Students used features such as calculators, calendars, clocks and timers, and accessing the internet. On a 4-point scale (1 = strongly disagree to 4 = strongly agree) students indicated high levels of agreement ($M = 3.53$, $SD = .55$) with the statement "I think mobile phones support

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learning." Further, students indicated that benefits of mobile phones in classrooms included: reduction of the digital divide between students who have technology and those who do not, provide learning opportunities, and improve digital fluency (Thomas et al., 2016).

Yeap, Ramayah, and Soto-Acosta (2016) also replicated the study by Cheon et al., (2012) using the Theory of Planned Behavior (TPB) to predict factors influencing adoption of m-learning in higher education. The study by Yeap et al., (2016) collected data from 900 undergraduates in a public university in Malaysia. The study confirmed that all three constructs – Behavioral beliefs, Normative beliefs, and Control beliefs – had a significant positive influence on student intentions to adopt m-learning. However, the study found that subjective norm had the strongest impact followed by perceived behavior control and finally attitude (Yeap et. al, 2016) as compared to perceived behavioral control having impact followed by attitudes and then subjective norms (Cheon et al., 2012). The study validated the model of m-learning readiness based on the TBP (Choen et al., 2012) and successfully proved that it holds true with a different population (Yeap et al., 2016).

Jeno, Grytnes, and Vandvik (2017) investigated biology students' intrinsic motivation using a mobile app – ArtsApp available for Android smartphones compared to traditional textbooks for species identification. The study found that students had higher intrinsic motivation ($M = 5.44$, $SD = 1.23$) compared to using the textbook ($M = 3.24$, $SD = 1.31$). Additionally, students scored higher on achievement tests with the mobile application than did students using textbooks (mobile application; $M = 7.78$, $SD = 3.21$, textbook; $M = 5.95$, $SD = 3.46$) (Jeno et al., 2017).

In a study by Mieshar-Tal and Ronen (2016) instructor attitudes about the use of a mobile game and its impacts on learning were examined. The study conducted a workshop using a mobile-game app with location-based services for creating treasure hunts. The game was designed to be an in-school activity. The study revealed that instructor attitudes about the potential of smartphones for learning was changed after the experiment and that a willingness to adopt them as part of student's personal learning toolkit was strengthened. Additionally, teachers' attitudes about positive effects of using smartphones in learning increased (Mieshar-Tal et al. 2016).

Al-Emran, Elsherif, and Shallan (2016) conducted a study with 383 undergraduate students and 54 instructors in five universities to explore the perceived usefulness of mobile devices in educational environments. Student participants were from four majors: Business management, English, IT, and Project management. The study was exploratory and utilized a 10-question survey. For both students and instructors, the results indicated no significant difference among attitudes towards the use of m-learning in terms of gender. The study did find a significant difference of attitudes for use of technology for learning in student who owned smartphones compared to those who did not. Further, the study indicated that almost all majors have a positive attitude towards m-learning and that both undergraduate and graduate students are motivated to use their mobile devices for learning. (Al-Emran et al. 2016). In summary, the study by Cheon et. al., (2012) using TBT to predict mobile learning readiness has been replicated and further validated by recent researchers indicating that students' intentions to use mobile devices for learning can aid in prediction of successful use of mobile devices in educational settings.

Discussion of Human Interactions with Mobile Devices

Nielsen and Molich (1990) developed a set of 10 heuristics for computer user interface design that are now commonplace in most human-computer interactions and are heavily relied upon within the mobile application (App) development community. These heuristics allow users to easily adopt new devices, software, Apps, and user interfaces based upon previous learned expectations and behaviors as well as speeding up development time for new products. Hobber (2013) found that 49% of smartphone users hold their device with one hand and the thumb in primary contact with the device screen. Billinghurst and Vu (2015) found that most users have a dominant hand interaction with their mobile device and use a single finger for most motions.

Summary and Research Questions

The purpose of this study was to investigate outcomes with mobile learning, distributed presentation, and testing on mobile devices. Specifically, the study investigated differences between distributed presentation microlearning outcomes based upon the number of evaluations after instruction and whether planned – once-daily instruction and testing; or the massed availability of instruction and testing, has an impact on learning outcomes. Additionally, this study examined pre- and post-instruction student attitudes about microlearning, mobile devices and mobile use in academic settings. The research questions for this study are:

1. Is there a difference in learning outcomes depending upon the method of delivery of instruction – distributed presentation or massed availability?

2. Is there an improvement in learning depending on the number of assessments after instruction?

3. What are students' attitudes about using personal mobile devices for learning?

4. What are students' beliefs about the ease of learning on mobile devices?

The study employed a 2 x 2 factorial design and compared differences in learning outcomes based on type of instructional presentation and time of delivery of assessment. The first of the two independent variables manipulated in this study were the distribution of presentation of instruction with two levels, once-per-day or the massed availability of instruction in which all learning modules were presented without restriction to availability. The second independent variable was testing with two levels, immediately upon completion of instruction or at the end of all instruction. The dependent variable was learning outcomes in the form of scores on the comprehensive quiz. Participant attitudes about learning on mobile devices were evaluated as covariates to the dependent variable and as attitudinal exploratory factor analysis.

CHAPTER 3

METHODS

Participant Characteristics

Participants for this study were a random sample of undergraduate and graduate students at Arizona State University (ASU). Participants were required to be at least 18 years of age and be able to sign legal consent. Beyond that, no restrictions were placed on the academic level, area of study or campus location of potential participants. Participants also had to be enrolled in classes at the time of the study with a valid ASU identification number. Participants were required to own a personal touch-enabled, wireless-capable smartphone device and agree to use it for the study. The study did not provide participants with any computers, mobile devices or smartphones. Participants needed a connection to a wireless network and the Blackboard LMS mobile application (App). A free wireless connection was available on all main ASU campuses and participants were not required to purchase wireless service to participate in the study. The Blackboard LMS App was free and available for download on Google Play for Android devices or iTunes for Apple iOS devices. All materials were only presented in English and no accommodations were made for persons with language barriers or disabilities. These conditions were clearly described in the online consent form.

Sampling Procedures

Sample size. To determine a sample size for the two-way ANOVA with two levels, an a-prior power analysis was conducted to using G*Power ($\alpha = .05$). Table 1 provides a summary of the power analysis.

Table 1

Summary of power analysis

Power	ρ^2		
	.10	.25	.40
.70	620	101	41
.80	787	128	52
.90	1053	171	68

The resulting sample size with Cohen's $f = 0.25$, alpha = .05, and power = .80 was 128 total participants, or 32 per condition. The family-wise Type I error rate was set at the 0.05 level. Cohen's f defines the following effect sizes: small $f = 0.10$, medium $f = 0.25$, large $f = 0.40$ (Cohen 1988).

Recruitment. Participants were recruited through online advertisements placed in the My ASU student portal, ASU Sport Teams, an ASU fraternity, and classes in Arts, Communications, and Educational Technology. A condition of the My ASU student portal advertisement was that the study had to be available to most students at the university. As a result, a very diverse group of students participated in the study. Various incentives were offered to participants: Amazon gift cards for the My ASU online portal, community service for the ASU Sport Teams and ASU fraternity, and extra credit for the class participants. The three forms of incentives were clearly outlined and described in the IRB to ensure equality of compensation.

All participants signed an online consent form through Google Docs (Appendix A) regardless of recruitment method and were enrolled in the instructional portion of the

study. The forms were authenticated through the Arizona State University user ID authentication portal to ensure that only ASU students participated in the study and enabling association of identification with survey responses and Blackboard instructional content completion. There were 311 total applicants; 137 completed the instructional content.

Demographics. The sample collected for this study was composed of 311 students. The data sources for the study included a pre-survey, mobile instruction with quizzes, and a post-survey. This produced five participant data sources for examination: 131 pre-survey only (42.1%), 10 post-survey only (3.2%), 33 pre- and post-survey but no instruction (10.6%), 40 only post-test missing (12.9%), and 97 all components (31.2%). A total of 301 participants completed the pre-instruction survey (96.8%) and 10 completed the post-survey only (3.2%). Reported gender was 171 males (55%), 130 females (41.8%) and 10 preferred not to disclose or were missing (3.2%). The academic level of achievement was 60 freshman (19.3%), 58 sophomore (18.6%), 69 junior (22.2%), 61 senior (19.6%), 53 graduate student (17%), and 10 missing or did not disclose (3.2%). The type of smartphone mobile device owned was 96 Android devices (30.9%), 204 Apple iOS devices (65.6%), 1 Windows device (0.3%), and 10 missing or did not disclose (3.2%). The age of the participants for the pre-instruction survey was; 148 18–20 years-old (47.6%), 104 21–24 years-old (33.4%), 35 25–30 years-old (11.3%), 14 31-or-older (4.5%) and 10 missing or did not disclose (3.2%). Participant area of study was too diverse to differentiate and areas of study included: Art, Business, Communications, Education, Engineering, Life Sciences, and Nursing.

A total of 137 participants completed the mobile instruction and some combination of the pre- and post-survey (none missing). Of these participants there were 75 males (54.7%) and 62 females (45.3%). The academic level of achievement was: 23 freshman (16.8%), 24 sophomores (17.5%), 32 juniors (23.4%), 29 seniors (21.2%), and 29 graduate students (21.2%). The type of smartphone mobile device owned was 44 Android devices (31.6%) and 93 Apple iOS devices (68.4%). The age of the participants was: 61 18–20 years-old (44.5%), 48 21–24 years-old (35.0%), 18 25–30 years-old (13.1%), and 10 31-or-older (7.4%). Participants were randomly assigned to one of the following instructional conditions.

1. One instructional module delivered each day, Monday – Friday, in which the daily instructional module and individual module quiz were available at 6:00 a.m. each morning and made unavailable at midnight each day. The final comprehensive quiz was available on Friday.

2. One instructional module delivered each day, Monday – Friday, in which the instruction was available at 6:00 a.m. each morning and made unavailable at midnight each day. This group only received the final comprehensive quiz, which was available on Friday.

3. All instructional modules available for self-pacing in which the instructional modules, individual quizzes, and final comprehensive quiz were available at 6:00 a.m. Monday and made unavailable at midnight Friday.

4. All instructional modules available for self-pacing in which the instructional modules and final comprehensive quiz were available at 6:00 a.m. Monday and made unavailable at midnight Friday.

Materials

To create a culture of full-mobile utilization, all consent forms, instructions, surveys and instructional content were set up to be available for viewing and completion on a smartphone. Custom online multimedia about lightning was created for this study and distributed through the Blackboard LMS. A single Blackboard master course was created and contained all instruction, quizzes, and announcements. From the master course, four duplicate courses were created, one for each of the four study conditions. Duplication of a single master course ensured consistent instruction and quiz questions, and enabled automated deployment of content availability and removal of availability for each participant group based on the study conditions. Course access was made unavailable at the end of each week for all participants enrolled in that week's research group. Announcements were sent daily to all participants. The participants in the groups that got daily instruction received both a morning announcement at 8:00 a.m. and an evening announcement at 6:00 p.m. (Appendix B). Participants were able to turn off announcements through the Blackboard user interface.

A technical job aid for how to use the app and access the content was created and placed in an online Google Doc (Appendix B). The pre- and post-surveys were also created using Google Forms and results were captured in a Google Sheet for analysis. The Google docs and forms were mobile responsive and fully functional on smartphones.

Almost half of smartphone users hold their device with one hand and most have a dominant hand interaction with their mobile device (Hobber, 2013; Billinghurst & Vu, 2015). For this study, the Blackboard App and controls native to the student's personal device type predetermined certain device controls.

The study did have control over how the content was designed and developed, and custom content was created to model common mobile application (App) behavior and mimicked common vertical App orientation on smartphone displays. Similar to an App interface the content was swipe-able and tap-able using a single digit for navigation. Due to the vast range of device and screen sizes some users may have experienced suboptimal single-digit access to controls.

Once created, the instructional materials were optimized for mobile devices (see Figure 1) and specifically designed to fit a vertical smartphone screen (see Figure 2) as compared to normal horizontal video and multimedia display. Creating this unique format allowed participants to optimally view and engage in the mobile content more seamlessly since they did not need to rotate their smartphones. The expected behavior was a simple swipe to the left or right, using a thumb or single finger to navigate the content, that users reflexively utilize when interacting with their smartphones. Common user interface design interactions, referred to as heuristics (Nielsen & Molich, 1990), were relied upon to improve adoption of a new system and to make participants feel more comfortable engaging with the instruction on their device.

Figure 1. Illustration of single-hand thumb navigation and user control (Wroblewski, 2012).

Figure 2. Illustration of custom formatting of instructional screens.

Learning Environment

Study procedure. Enrollment in the study ran for approximately 15 weeks throughout a normal academic semester. Participants who completed the consent form were randomly assigned to one of the four conditions and enrolled in the Blackboard instruction on a rolling basis. All instruction began on a Monday and ended on a Friday, simulating traditional academic course work. Some weeks as many as 80% of enrolled participants failed to complete the instruction. Participants were not allowed to re-enroll, take modules or quizzes over or switch to another group. Participants in all conditions received the same learning content and final quiz questions.

Each weekend new participants were sent a message from Blackboard in the form of an email announcement (Appendix E). The announcement reminded participants that they were enrolled in a research study. On each Monday, the new group of participants would begin to receive daily announcements about the study. The announcements for the distributed presentation groups would receive a morning and afternoon announcement reminding them that availability for the day's content would end at midnight. Once-daily announcements were also sent for the massed presentation participants, but the announcement reminded them that availability to the study content would end at midnight on Friday.

Instructional content. The learning modules consisted of approximately 25 total minutes of instructional content, five module quizzes, and a final comprehensive quiz. The video content was created using a combination of Camtasia, an audio and video editing program; Adobe Illustrator, a drawing program; and PowerPoint. The content storyboards were drafted in PowerPoint and the custom illustrations were created to

accompany the audio, which was recorded in Camtasia. Once the illustrations and audio were combined in Camtasia to create a movie, the movie was saved in a custom format of 320 pixels wide by 480 pixels tall. Multiple tests were performed to find an ideal compression level so that the video files were not overly large causing buffering and bandwidth problems for smartphones.

Participants were informed that they would need to turn on the speaker on their smartphone or use headphones. A few participants indicated a problem with newer Bluetooth enable headphones and other participants needed additional assistance turning on the sound on their smartphones. Assistance was provided in the form of screen captures and instructions via email.

Compared to traditional online instruction, where content, links, and resources are often presented on multiple screens in the same browser window, the microlearning instruction was presented as a single informational unit (SIU) that fits on a single smartphone screen. Each SIU contained a short headline or keywords and illustrations essential to the instruction. The use of headlines and or keywords in instruction is known as signaling. The content was carefully curated to ensure concepts per microlearning instructional unit were discrete. This approach is similar to the Micro Units created by Beutner and Pechuel (2017) in which small units of learning content only fill one screen.

At the beginning of each module, an introductory screen appeared with the title of the instructional module, i.e., *How Lightning Works.* Modules were broken into microlearning instructional units of between approximately 30 seconds to 1 minute. The same narrator was ued to minimize disparity in accent, dictation, pacing or pronunciation.

A sample microlearning session typically included two or three SIUs accompanied by narration.

Figure 3. Screen of Single Informational Unit.

Narration: "*The smaller positively charged particles tend to rise while the larger negatively charged particles gravitate toward the bottom of clouds. These particles tend to separate under the influences of updrafts and gravity until the upper portion of the cloud acquires a net positive charge and the lower portion of the cloud becomes negatively charged.*" (A Lightning Primer, National Air and Space Administration [NASA.gov] n.d.)

Participant activity logs were not always available due to lack of functionality with the current version of Blackboard and database integration with student identification numbers at ASU. To verify completion, participants signed an acknowledgment (Figure 4) at the end of each module that they viewed all content within

the module. While this was not fool-proof, it is a common check of student integrity in online courses.

Measures

Attitudinal pre-instruction survey. After completing the consent form, and before taking the instruction, participants were asked to complete a survey. The survey collected demographic information, the number of mobile and other computing devices, hours spent using technology, and attitudes about learning on mobile devices (Appendix C). The attitudinal questions consisted of 15 Likert-scale items. The instrument was adapted from Cheon, Lee, Crooks, and Song (2012) study investigating mobile learning readiness in higher education. Cronbach's Alpha for the individual measurement items in the Cheon et al. (2012) study was between .879 and .94. All 15 items of the pre-instruction survey were initially combined to create a new variable to calculate Cronbach's Alpha for the reliability of the scale. Cronbach's Alpha for the variable was .927, which indicates that the scale meets conventional standards of scale reliability.

Instructional quizzes. All participants who completed the instruction took a 10-question quiz. The quiz consisted of five multiple-choice questions and five short answer questions. One multiple-choice question and one short answer question was derived from each module (Appendix J). Testing had two conditions: immediately upon completion of instruction or at the end of all instruction. Participants in the first condition also received a five-question quiz at the end of each module, thus completing six total quizzes (Appendix K). The individual modules quizzes consisted of four multiple-choice questions and one short answer question. A limitation of the study is that two conditions did not receive the five additional module quizzes.

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Multiple-choice questions consisted of five answer choices. Of the five answers, some answers were weighted more than other answers. Each question had an answer that was worth 10 points, and other answers were scored: 0, 3, 5, 7, or 10. The scoring scale was utilized to increase the variability of scores so that scores were not in clusters of multiples of 5 and 10.

Short answer questions were incorporated into both testing conditions to decrease guessing and to facilitate transfer skills. Short-answer questions were based on the instrument created by Johnson and Mayer (2009) but were revised and expanded to include content created for the instructional modules. Johnson and Mayer (2009) indicated that transfer questions are not as rhetorical in nature, are more conceptual, and challenge students to use a problem-solving approach to instruction. Short answer questions were also scored: 0, 3, 5, 7, or 10.

Quizzes were created using the Blackboard Mobile compatible test type. The tests were completed on the participants' smartphones in the same course content area as the instructional modules. Participants swiped a virtual string at the beginning of the quiz, unlocking the content (Figure 4).
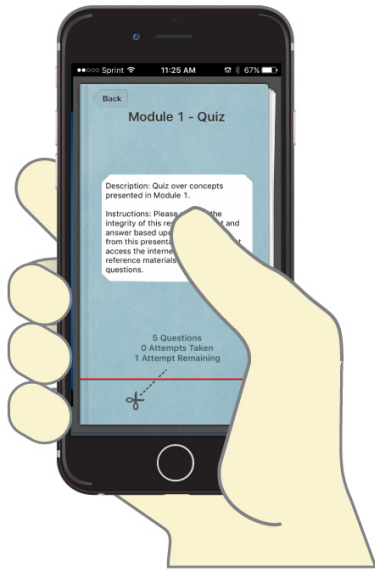
Figure 4. Example of acknowledgments of integrity unlocks screen for quizzes.

Each quiz question fit on a single screen (Figure 5) to decrease cognitive load and mimic a single informational unit, similar to the instructional modules. The advantage of a common user interface for both the instruction and the evaluation is that users became familiar with the interface, facilitating ease and access to content and quizzes.
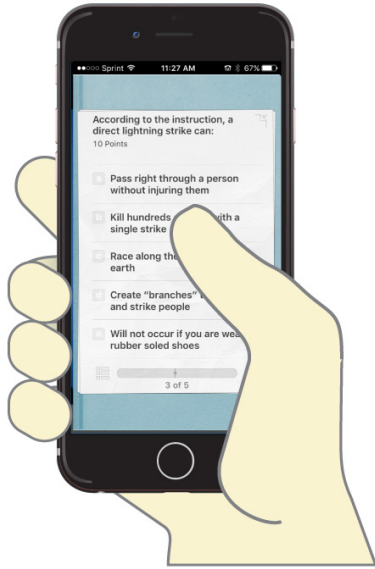
Figure 5. Example of multiple choice quiz question screen.

Short answer transfer questions accessed the smartphone keypad. Short answers were limited to 300 characters, approximately double the length of a Twitter social-media post. The character limit was chosen so that participants did not feel compelled to write a short essay in order to answer questions. Answers could be as short as a few words to convey understanding. Answers that reflected a deeper understanding of the instruction were assigned 10 points. Answers that reflected a rudimentary understanding of instruction were assigned a lower score.

Example: Final quiz, Module 1 assessment.

Question 2: An indirect strike can be very dangerous because:

Sample 10-point participant answer: *The electrical current finds a better path in humans and releases the charge. Hence they become part of the flash channel. Various objects on the person can amplify the effects and cause serious damage to the individual. Such as burns and neurological damage.*

Sample 7-point participant answer: *Because when it strikes someone electricity runs through their whole bodies.*

Sample 5-point participant answer: *it can cause explosions that are very dangerous.*

Example: Final quiz, Module 4 assessment

Question 8: Lightning might strike the ground instead of a nearby tree because:

Sample 10-point participant answer: *The lightening often seeks the path of least resistance, which might be the ground rather than the tree. The ground is more positively charged than the tree, making the ground a better target.*

Some participants did indicate in the open-ended survey response that they wished there were more characters available to answer short-answer questions.

Scoring. All quiz results were collected electronically. Multiple-choice answers were assigned a predetermined value and automatically scored in Blackboard. Short answers were individually scored on the scoring scale checking for completeness and accuracy of the answer. A second grader was not utilized because the answers were short and discrete, so no inter-grader reliability was tested.

Some short answers did receive a score of zero. An example of a short answer that received a score of zero in response to any question was: "*I do not remember.*" Although it is unfortunate that some participants did not remember, it is considered better for the honest answer of not remembering than to find that participants searched the internet for answers to questions.

Attitudinal post-instruction survey. After completing the pre-instruction survey, the instruction and all quizzes, the participants were asked to complete a post-instruction survey. The survey collected 10 additional attitudinal questions utilizing the same Likert-scale. This instrument was also adapted from the Cheon et al. (2012) study. All 10 items of the post-instruction survey were initially combined to create a new variable to calculate Cronbach's Alpha. Cronbach's Alpha for the variable was .903, which indicates that the scale meets conventional standards of scale reliability.

CHAPTER 4

RESULTS

The primary goal of this research study was to investigate learning improvement

and outcomes based on delivery of instructional content and assessment of instructional

content after completion. To measure this a one-way, two-way, and three-way or factorial

ANOVA were conducted to compare differences in learning outcomes based on the type

of delivery of instructional content, the number of assessments, the factorial ANOVA,

and gender. There were two independent variables manipulated in this study. The first

independent variable was delivery of presentation of instruction, with two levels – once-

per-day or massed availability in which all instruction was made presented without

restriction to availability. The second independent variable was testing with two levels –

quizzes for each individual learning module and a comprehensive quiz or a single

comprehensive quiz at the end of all instruction. The dependent variable was learning

outcomes in the form of scores on the comprehensive quiz.

The final study achieved 137 participants in the instructional portion. Scores

ranged from 28 – 100, $M = 71.57$, $SD = 16.28$. A post hoc power analysis using G*Power

with Cohen's $f = 0.25$ and alpha = .05 resulted in power = .83. Participant groups were as

follows: 34 daily instruction with all quizzes, 36 daily instruction with only a final quiz,

32 all instruction at once with all quizzes, 35 all instruction at once with only a final quiz.

Outliers were explored using boxplots. One condition; daily instruction with the final

quiz only, had an outlier, but the outlier was not greater than 3 box-lengths from the edge

of the boxplot (Figure 6). The outlier was not removed. Table 2 presents a summary of

the study's research questions and the tests conducted.

GroupA–Delivery of Instruction: Daily instruction, GroupB–Number of quizzes: 1 final quiz only
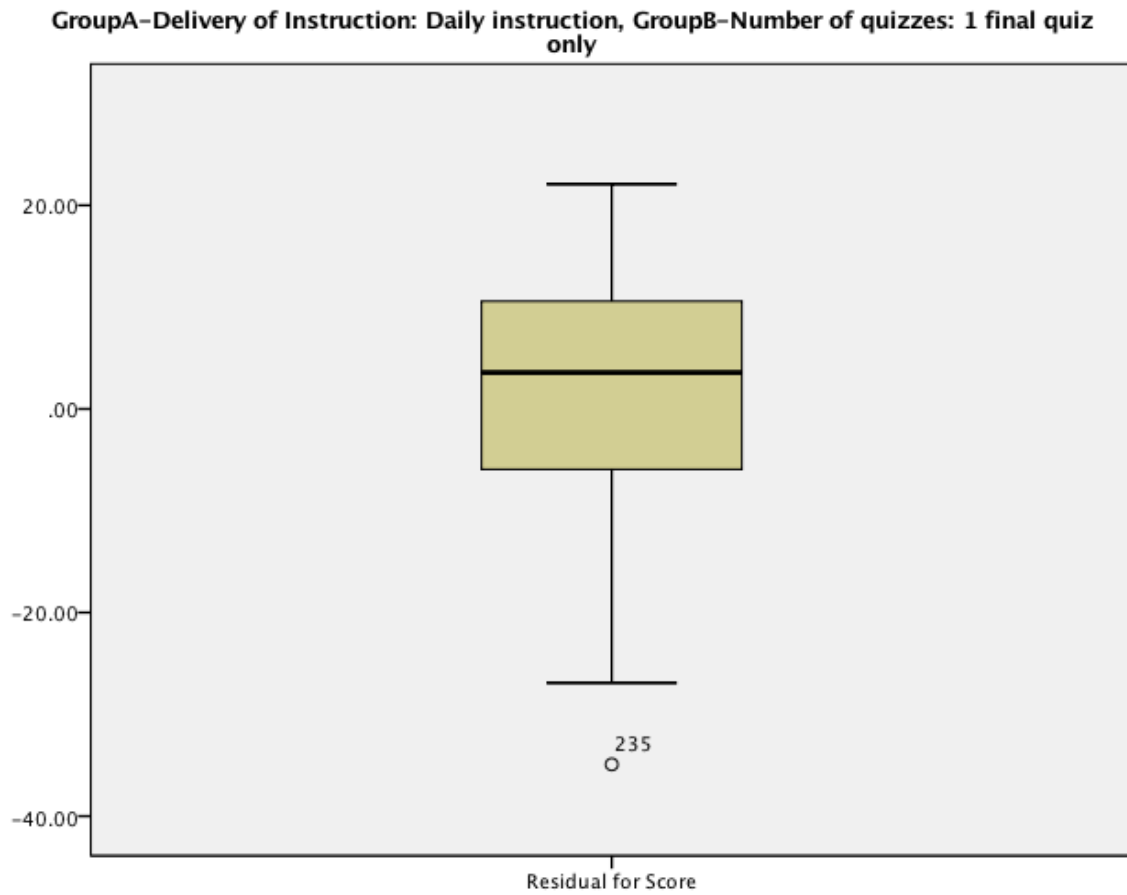
Figure 6. Boxplot of outlier less than 3 box-lengths from the edge of the boxplot.

Table 2

Tests Conducted

	Hypothesis	Data Source	Analyses
H1	There is a relationship between delivery of instruction and learning outcomes.	Learning Measure Scores	Analysis of Variance
H2	There is a relationship between the amount of testing and learning outcomes.	Learning Measure Scores	Analysis of Variance

Tests Conducted

H3	There is a relationship between students' attitudes about using personal mobile devices and a willingness to engage in learning on their devices.	Survey Data	Exploratory Factor Analysis Analysis of Variance
H4	There is a relationship between students' beliefs about their technical abilities to use mobile devices and their willingness to engage in learning on mobile devices.	Survey Data	Exploratory Factor Analysis Analysis of Covariance

Learning Outcomes

One-way ANOVA. A one-way ANOVA was conducted to evaluate learning outcome scores first by type of distribution of instruction (daily or group) and next by the number of quizzes (one quiz for each module plus a comprehensive quiz and the final quiz or final quiz only).

The independent variable, the distribution of instruction, had two levels: daily delivery of instruction in which individual daily instruction was available at 6:00 a.m. each morning and made unavailable at midnight each day, Monday – Friday, and massed instruction in which all instructional modules and quizzes were available at 6:00 a.m. Monday and made unavailable at midnight Friday of that same week. The dependent variable was learning outcomes in the form of final quiz score results from the first group to the second group. Table 3 shows the sample size, mean, and standard deviation for the dependent variable. The ANOVA was not significant, $F (1, 135) = .23$, $MSE = 61.42$, $p = .63$. The partial $\eta^2 = .00$ indicates a very low effect size. Homogeneity of variances

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was observed as assessed by Levene's test for equality of variances $F = .00$, $p = .98$.

Post hoc tests were not performed because there were fewer than three groups.

Table 3.

Learning Outcome by Delivery of Instruction

	N	Mean	SD
Daily	70	70.91	16.33
Massed	67	72.25	16.33

The independent variable, number of quizzes, had two levels: one quiz for each module plus a comprehensive quiz – six total, and comprehensive quiz only. The dependent variable was learning outcomes in the form of final quiz score results from the first group to the second group. Table 3 shows the sample size, mean, and standard deviation for the dependent variable. The ANOVA was significant, $F (1, 135) = 4.01$, $p = .047$. The partial $\eta^2 = .03$ indicates a large effect size. Homogeneity of variances was observed as assessed by Levene's test for equality of variances $F = .04$, $p = .84$. Post hoc tests were not performed because there were fewer than three groups.

Table 4.

Learning Outcome by Number of Quizzes

	N	Mean	SD
All quizzes	66	68.71	17.05
Final quiz only	71	74.23	15.17

Two-way ANOVA Test of Main and Interaction Effects. A two-way ANOVA was conducted to compare the main effects of the distribution of instruction and testing and the interaction effect between distribution of instruction and testing on final quiz scores. The two independent variables (distribution of instruction, number of tests) each had two levels: distribution of instruction (daily or distributed instruction and massed instruction) and number of tests (five intermediate quizzes plus one comprehensive quiz and comprehensive quiz only). The dependent variable was learning outcomes in the form of final quiz score results. There were no outliers in data greater than 3 box-lengths from the edge of the box as assessed by inspection of a boxplot. Homogeneity of variances was observed, as assessed by Levene's test for equality of variances indicated $F = .11$, $p = .96$. None of the effects were statistically significant at the .05 significance level. The main effect for delivery of instruction type yielded $F(1, 133) = .26$, $MSE = 66.82$, $p = .61$, $\eta^2 = .002$, indicating no significant difference between daily delivery of instruction ($M = 70.80$, $SD = 1.93$) and massed delivery of instruction ($M = 72.20$, $SD = 1.98$). The main effect for testing yielded $F(1, 133) = 3.88$, $MSE = 1011.56$, $p = .05$, $\eta^2 = .03$, indicating no significant difference between five intermediate quizzes plus one comprehensive quiz ($M = 68.78$, $SD = 1.99$) and one comprehensive quiz only ($M = 74.26$, $SD = 1.92$). The interaction effect was not significant, $F(1, 133) = 1.03$, $MSE = 268.10$, $p = .31$, $\eta^2 = .01$. Table 5 shows the sample size, mean, and standard deviation for the dependent variable.

Table 5.

Learning Outcome by Delivery of Instruction and Number of Quizzes

Distribution	All Quizzes			Final Quiz Only		
	N	Mean	SD	N	Mean	SD
Daily	34	66.68	16.91	36	74.92	14.91
Massed	32	70.88	17.20	35	73.51	15.62

The estimated marginal means plots were examined (Figure 7, Figure 8). A disordinal interaction appeared in one plot (Figure 8) and a follow-up test was performed for the simple effects of number of quizzes within each level combination of the delivery of instruction. There was a significant difference between groups when using daily delivery of instruction and the final quiz only $F(1, 133) = 4.55$, $p = .04$, partial $\eta^2 = .03$. However, there was no significant difference between groups when using daily delivery of instruction and all quizzes.
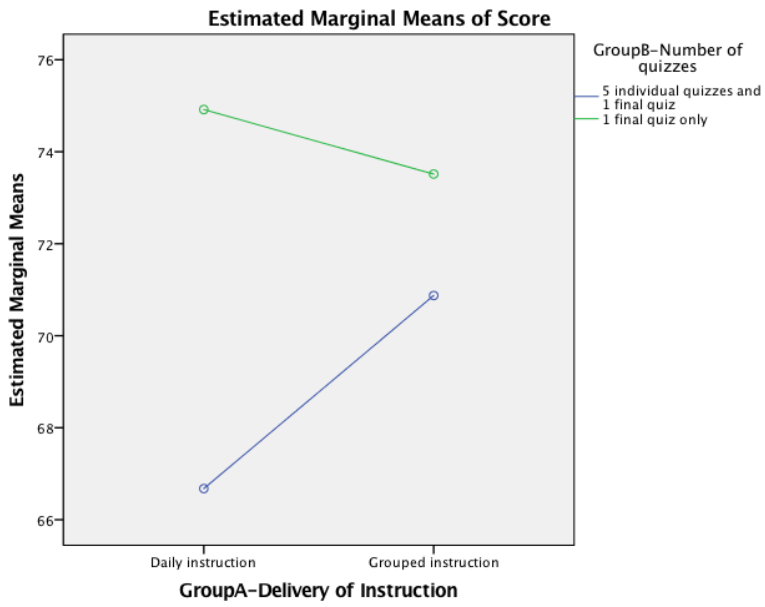
Figure 7. Plot of estimated marginal means for Delivery of Instruction showing no interaction between groups.
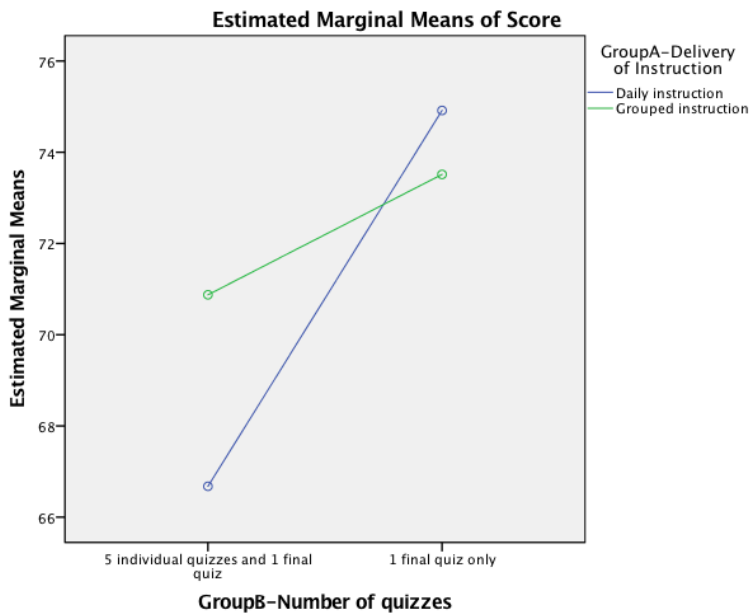
Figure 8. Plot of estimated marginal means for Testing shows a significant interaction between groups.

Three-way or factorial ANOVA. A 3 x 2 factorial ANOVA was conducted.

There were three independent variables each having two levels. The independent

variable, the distribution of instruction, had two levels: daily delivery of instruction in

which individual daily instruction was available at 6:00 a.m. each morning and made

unavailable at midnight each day, Monday – Friday, and massed instruction in which all

instructional modules and quizzes were available at 6:00 a.m. Monday and made

unavailable at midnight Friday of that same week. The second independent variable,

number of quizzes, had two levels: quizzes for individual modules plus a comprehensive

quiz – six total, and comprehensive quiz only. The third independent variable was gender,

which had two levels: male and female. The dependent variable was learning outcomes in

the form of final quiz score results from the first group to the second group. To evaluate

the effect of distribution (daily or massed) and quizzes (all quizzes or final quiz only) on

participants learning outcome scores. There were no outliers in data greater than 3 box-

lengths from the edge of the box as assessed by inspection of a boxplot. Quiz scores were

normally distributed ($p > .05$) except for two groups (females in the daily distribution of

instruction with all quizzes, $p = .045$, and males in the daily delivery of instruction with

the final quiz only, $p = .03$), as assessed by Shapiro-Wilk's test of normality.

Homogeneity of variances was observed, as assessed by Levene's test for equality of

variances indicated $F = .97$, $p = .45$.

There was no statistically significant interaction between delivery of instruction,

the number of quizzes, and gender for the dependent variable outcome scores $F(1, 129)$

$= .04$, $MSE = 10.30$, $p = .84$. The partial $\eta^2 = .00$ indicates a very low effect size. Table 6

shows the sample size, mean, and standard deviation for the dependent variable.

Table 6.

Learning Outcome by Delivery of Instruction, Number of Quizzes and Gender

	All Quizzes				Final Quiz Only		
Delivery	N	Mean	SD		N	Mean	SD
Daily	34	66.68	16.91		36	74.92	14.91
Male	13	61.92	18.13		24	72.88	16.45
Female	21	69.92	15.84		12	79.00	14.91
Learning Outcome by Delivery of Instruction, Number of Quizzes and Gender							
Massed	32	70.88	17.20		35	73.51	15.62
Male	16	67.06	19.91		23	72.22	16.96
Female	16	74.69	13.58		12	76.00	13.00

Participant Mobile Device Characteristics

A pre-instruction survey collected participant characteristics data related to ownership and usage of personal mobile devices and other laptops or desktops. Participants indicated a high level of ownership of more than one mobile device ($N = 182$, 58.5%) and 95.8% indicated they owned at least one laptop or desktop in addition to their other mobile devices. Approximately 67.5% ($N = 210$) of participants indicated that they used their mobile device for some type of classroom support and of those 20.9% reported mobile device use a few times per week to support learning in the classroom. The results are shown in Table 7.

Table 7.

Characteristics of Participant Mobile and Laptop or Desktop Device Ownership and Usage (N = 311)

Characteristic	*n*	%
Mobile device (smartphone and/or tablet) ownership		
1 device	98	31.5
2 devices	182	58.5
3 devices	16	5.1
4 devices	5	1.6
Missing	10	3.2
Hours per-day of mobile device(s) use		
Less than 1 hour per day	7	2.3
1–3 hours per day	119	38.3
4–5 hours per day	96	30.9
6–7 hours per day	43	13.8
7 or more hours per day	36	11.6
Missing	10	3.2
Desktop or laptop ownership in addition to mobile device ownership		
1 laptop or desktop	214	68.8
2 laptop or desktop	63	20.3
3 laptop or desktop	6	1.9
4 or more	15	4.8
Missing	13	4.2
Hours per-day of desktop or laptop computer use separate from mobile device use		
1 hour per day	32	10.3
2–3 hours per day	113	36.3
4–5 hours per day	87	28.0
6 or more hours per day	68	21.9
Missing	11	3.5
Number of alerts, announcements, and classroom information sent to mobile devices by instructors		
None	97	31.2
1–3	85	27.3
4–5	67	21.5
6–7	16	5.1
8 or more	34	10.9
Missing	12	3.9

Characteristic	n	%
Use of a mobile device to support learning during class		
Yes	210	67.5
No	89	28.6
Missing	12	3.9
Frequency of mobile device use to support learning in class		
A couple of times per month	90	28.9
Once per week	28	9.0
A few times per week	65	20.9
Daily	43	13.8
No or missing	85	27.3

Attitudes

Two surveys were created to explore participant attitudes about learning on mobile devices. The pre-instruction survey ($N = 301$) consisted of 15 items with five-point Likert scale range. The post-instruction survey consisted of 10 items with a five-point Likert scale range. The post-instruction survey also included an opportunity for participants to provide open-ended responses. Responses to both surveys ranged from *Not at all well* (1) to *Extremely well* (5) with values in parentheses assigned to scale items for analysis. Scale items had a high degree of reliability as determined by Cronbach's Alpha. Means, standard deviation, and Cronbach's Alpha if the item is deleted are shown for Pre-instruction survey items in Table 8 and Post-survey items in Table 9.

Table 8.

Descriptive Statistics for Pre-instruction Attitude Measures

		M	*SD*	*Alpha if item deleted*
1.	I would be interested in receiving educational content on my mobile device.	3.12	1.29	0.93
2.	It is acceptable for instructors to contact me with class-related information, announcements, alerts and reminders about assignments on my personal mobile device.	3.66	1.39	0.93
3.	I think learning on a mobile device can meet the needs of my current instruction.	2.85	1.12	0.92
4.	I think mobile devices could improve my ability to learn.	2.98	1.09	0.92
5.	I think mobile devices can help me stay on top of assignments and instruction.	3.57	1.15	0.93
6.	I think mobile devices could help me get my assignments completed more quickly.	2.96	1.22	0.92
7.	I think I can use my mobile device to learn all my course content.	2.24	1.13	0.92
8.	I would like my coursework more if it included more mobile learning.	2.55	1.17	0.92
9.	Using mobile learning in my coursework would be a pleasant experience.	2.91	1.03	0.92
10.	Including mobile learning in coursework is a good idea.	3.07	1.1	0.92
11.	I think my instructors possess adequate technical skills to use mobile devices effectively in the presentation and preparation of course content.	2.90	1.05	0.92
12.	I think my instructors possess adequate technical skills to use mobile devices effectively for quizzes and creating homework assignments.	2.89	1.11	0.93
13.	I think my instructors would be in favor of utilizing mobile learning in their courses.	2.57	1.07	0.92
14.	I think my fellow students would be in favor of utilizing mobile learning in their coursework.	3.35	1.10	0.92
15.	I think my instructors believe that a mobile device could be a useful educational tool in their coursework.	2.80	1.06	0.92

Note. N = 301

Table 9.

Descriptive Statistics for Post-instruction Attitude Measures

	M	*SD*	*Alpha if item deleted*
1. The degree to which you would be interested in receiving educational content on your mobile device. [a]	2.94	1.29	0.89
2. Your attitude about instructors contacting you on your mobile device.	3.57	1.42	0.91
3. Your attitude about how well do you think learning on a mobile device can meet your instructional needs.	2.60	1.19	0.88
4. Your attitude to which the technology used for this instruction worked on your mobile device.	3.14	1.10	0.90
5. Your belief that you have the technical skills to use your mobile device for learning.	4.12	.997	0.91
6. Your belief that accessing courses on your mobile device would be easy	3.54	1.12	0.89
7. Your belief that you would have more learning opportunities if your coursework were available on mobile devices.	2.81	1.30	0.88
8. Your belief that you would enjoy your courses more if instruction were available on mobile devices.	2.51	1.22	0.80
9. Your belief that having your instruction available on a mobile device would help you stay on track with your coursework.	2.83	1.27	0.88
10. Your belief that learning on mobile devices is the wave of the future. [b]	2.69	.919	0.90

Note. N = 138.
[a] Scale 1–5: 1=not at all, 5=I would like to receive all my instruction on my mobile device
[b] Scale 1–4: 1=not at all, 4=definitely

Analysis of Pre-instruction Attitudinal Measures. The pre-instruction survey

was used to examine student attitudes about mobile devices and to determine if there

were any underlying constructs. A principal axis factoring using Varimax (orthogonal)

rotation was employed to determine if the 15 items could be reduced and simplified. The

Kaiser-Meyer-Olkin (KMO) and Bartlett's test of sphericity were used for sampling

adequacy. Kaiser-Meyer Olkin measure of sampling adequacy (KMO = .95) and

Bartlett's test of sphericity < .001. Eigenvalues > 1 were considered for retention. Factor

1 explained 51.52% of the variance, Factor 2 explained 10.23% of the variance, and

Factor 3 explained 7.06% of the variance. Three factors were retained and are shown in

Table 10 and the scree plot is shown in Figure 9.

Table 10.

Total Variance Explained Pre-instruction Survey Items

	Initial Eigenvalues			Extraction Sums of Squared			Rotation Sums of Squared		
Factor	Total	% of Variance	Cum. %	Total	% of Variance	Cum. %	Total	% of Variance	Cum. %
1	7.727	51.516	51.516	7.727	51.516	51.516	4.768	31.785	31.785
2	1.534	10.227	61.743	1.534	10.227	61.743	3.059	20.395	52.181
3	1.058	7.056	68.799	1.058	7.056	68.799	2.493	16.618	68.799
4	0.77	5.135	73.934						
5	0.661	4.406	78.34						
6	0.547	3.649	81.989						
7	0.472	3.144	85.134						
8	0.405	2.699	87.832						
9	0.367	2.444	90.277						
10	0.32	2.132	92.408						
11	0.291	1.937	94.345						
12	0.246	1.638	95.983						
13	0.23	1.533	97.516						
14	0.211	1.405	98.921						
15	0.162	1.079	100						

Extraction Method: Principal Axis Factoring.
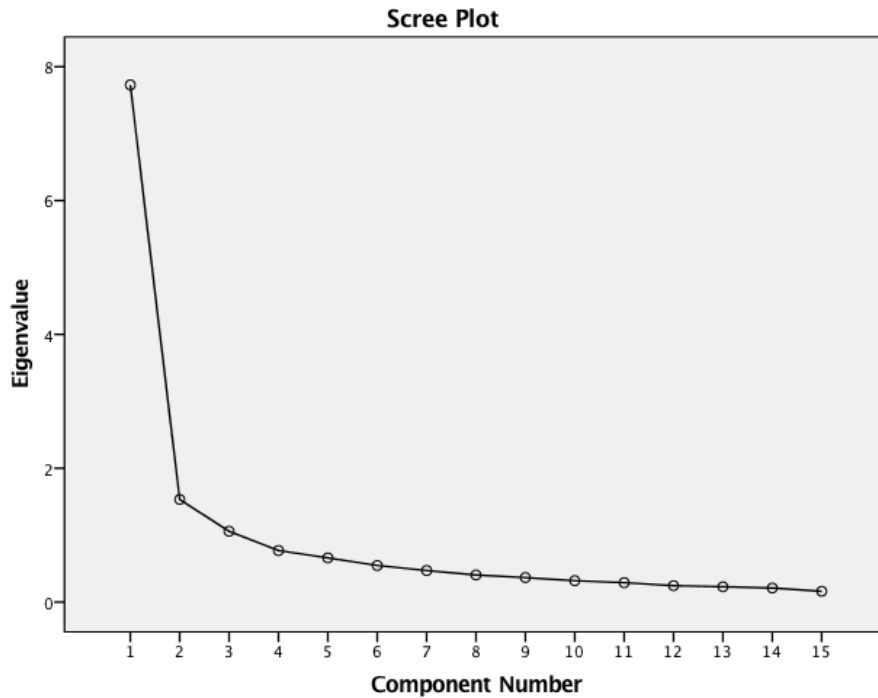
Scree Plot

Figure 9. Scree Plot for Pre-instruction Survey.

Factor 3 was very close to one, so a Parallel Analysis using a web-based tool created by Patil et al. (2008) re-examined the number of factors shown in Table 11. Since the original value for the third factor (1.058) was smaller than the corrected factor mean Eigenvalue (1.243) the third factor was not retained and the principal component analysis was reevaluated using Varimax rotation. Results of the new orthogonal rotation show a two-factor solution. Kaiser-Meyer Olkin measure of sampling adequacy (KMO = .93) and Bartlett's test of sphericity < .001. Following recommendations made based on criteria by Hair, Anderson, Tatham, and Black (1988) a value of .40 was considered as the minimum loading for a given item and a value of .60 was considered to load highly. Five items loaded on both components, Q7, Q8, Q9, Q10, and Q14 (Table 12). Items

loading on both factors were removed, and the resulting Rotated Component Matrix

displays two factors show in Table 13.

Table 11.

Eigenvalues from Patil et al. (2008) compared to values from SPSS

Patil et. al		SPSS	
Factor	Total	Factor	Total
1	1.400	1	7.73
2	1.306	2	1.53
3	1.243	3	1.06
4	1.183	4	0.77
5	1.129	5	0.66
6	1.078	6	0.55
7	1.031	7	0.47
8	0.984	8	0.41
9	0.940	9	0.37
10	0.903	10	0.32
11	0.855	11	0.29
12	0.813	12	0.25
13	0.767	13	0.23
14	0.714	14	0.21
15	0.651	15	0.16

Table 12.

Summary of Rotated Component Matrix loadings of a Two-Factor Solution for Pre-instruction Student Attitudes about Learning on Mobile Devices

		Component	
		1	2
Q3	I think learning on a mobile device can meet the needs of my current instruction.	0.766	
Q1	I would be interested in receiving educational content on my mobile device.	0.752	
Q4	I think mobile devices could improve my ability to learn.	0.726	
Q9	Using mobile learning in my coursework would be a pleasant experience.	0.704	0.511
Q6	I think mobile devices could help me get my assignments completed more quickly.	0.681	
Q10	Including mobile learning in coursework is a good idea.	0.666	0.505
Q5	I think mobile devices can help me stay on top of assignments and instruction.	0.646	
Q2	It is acceptable for instructors to contact me with class-related information, announcements, alerts and reminders about assignments on my personal mobile device.	0.628	
Q8	I would like my coursework more if it included more mobile learning.	0.624	0.539
Q14	I think my fellow students would be in favor of utilizing mobile learning in their coursework.	0.583	0.426
Q13	I think my instructors would be in favor of utilizing mobile learning in their courses.		0.813
Q12	I think my instructors possess adequate technical skills to use mobile devices effectively for quizzes and creating homework assignments.		0.803
Q11	I think my instructors possess adequate technical skills to use mobile devices effectively in the presentation and preparation of course content.		0.794
Q15	I think my instructors believe that a mobile device could be a useful educational tool in their coursework.		0.727
Q7	I think I can use my mobile device to learn all my course content.	0.486	0.583

Extraction Method: Principal Axis Factoring. Rotation Method: Varimax with Kaiser Normalization.

Table 13.

Component Identification for a Two-Factor Solution for Pre-Instruction Student Attitudes about Learning Mobile Devices

		Component	
		1	2
Component 1: Student Perceptions about the use of Their Personal Mobile Devices for Learning			
Q1	I would be interested in receiving educational content on my mobile device.	.769	
Q3	I think learning on a mobile device can meet the needs of my current instruction.	.762	
Q4	I think mobile devices could improve my ability to learn.	.729	
Q2	It is acceptable for instructors to contact me with class-related information, announcements, alerts and reminders about assignments on my personal mobile device.	.684	
Q6	I think mobile devices could help me get my assignments completed more quickly.	.683	
Q5	I think mobile devices can help me stay on-top of assignments and instruction.	.682	
Component 2: Student Perceptions about Instructors Beliefs and Mobile Devices for Learning			
Q12	I think my instructors possess adequate technical skills to use mobile devices effectively for quizzes and creating homework assignments.		.833
Q11	I think my instructors possess adequate technical skills to use mobile devices effectively in the presentation and preparation of course content.		.820
Q13	I think my instructors would be in favor of utilizing mobile learning in their courses.		.816
Q15	I think my instructors believe that a mobile device could be a useful educational tool in their coursework.		.743

Extraction Method: Principal Axis Factoring. Rotation Method: Varimax with Kaiser Normalization.

The two components were labeled and a mean attitudinal score was calculated for each factor. Factor 1, student perceptions about their own use of mobile devices in education ($M = 3.19$, $SD = 0.90$), and Factor 2, student perceptions about their

instructors' beliefs about the use of mobile devices in education ($M = 2.79$, $SD = .89$).

Gender was examined as an independent variable; Factor 1 males ($N = 171$, $M = 3.18$, $SD = .89$), females ($N = 130$, $M = 3.21$, $SD = .97$) and Factor 2 males ($N = 171$, $M = 2.87$, $SD = .88$), females $N = 171$, $M = 2.68$, $SD = .89$). A one-way ANOVA was conducted for both factors based on gender and mean attitudes scores. There was no significant interaction between genders for Factor 1 $F(1, 299) = .12$, $MSE = .095$, $p = .734$. There was no significant interaction between genders for Factor 2 $F(1, 299) = 3.53$, $MSE = 2.78$, $p = .061$.

Analysis of Post-instruction Attitudinal Measures. Using the same approach, the 10 post-instruction survey items were examined ($N = 140$). The Kaiser-Meyer-Olkin (KMO) and Bartlett's test of sphericity were used for sampling adequacy. Kaiser-Meyer Olkin measure of sampling adequacy (KMO = .92) and Bartlett's test of sphericity < .001. Eigenvalues > 1 were considered for retention. Only one factor had an Eigenvalue > 1, it explained 55.30% of the variance shown in Table 14 and scree plot in Figure 10. The component matrix could not be rotated. Using the Hair et al. (1988) criteria, one item; Q5 Your belief that you have the technical skills to use your mobile device for learning scored less than .40 and was removed. An additional item, Q10 Your belief that mobile learning is the wave of the future was also removed because it used a different scale, see Table 15.

Table 14.

Total Variance Explained Post-instruction Survey Items

	Initial Eigenvalues			Extraction Sums of Squared		
Factor	Total	% of Variance	Cum. %	Total	% of Variance	Cum. %
1	5.533	55.330	55.330	5.533	55.330	55.330
2	.986	9.859	65.189			
3	.808	8.081	73.269			
4	.708	7.078	80.347			
5	.578	5.783	86.130			
6	.417	4.166	90.296			
7	.383	3.833	94.129			
8	.257	2.571	96.700			
9	.176	1.761	98.461			
10	.154	1.539	100.000			

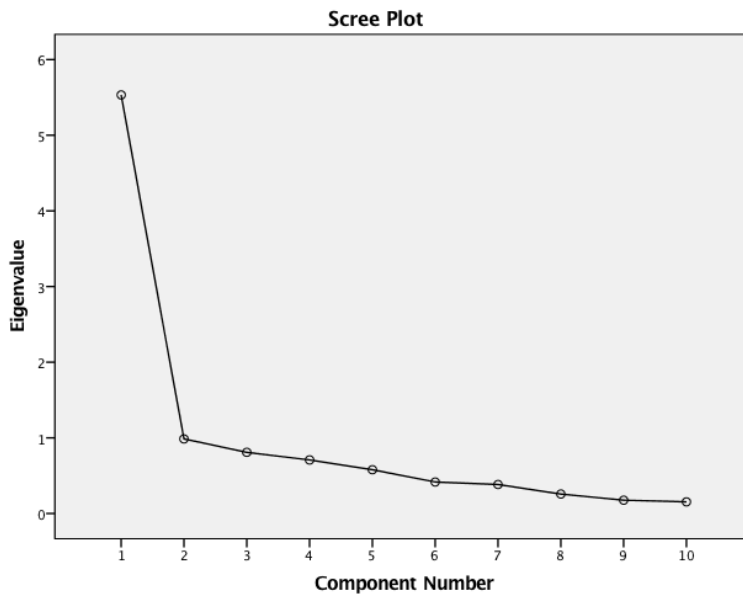Extraction Method: Principal Axis Factoring.

Figure 10. Scree Plot for Post-instruction Survey.

Table 15.

Summary of Matrix loadings of a One-Factor Solution for Post-Instruction Student Attitudes about Learning on Mobile Devices

		Component[a]
		1
Q7	Your belief that you would have more learning opportunities if your coursework were available on mobile devices.	.907
Q3	Your attitude about how well do you think learning on a mobile device can meet your instructional needs.	.886
Q8	Your belief that you would enjoy your courses more if instruction were available on mobile devices.	.876
Q9	Your belief that having your instruction available on a mobile device would help you stay on track with your coursework.	.840
Q1	The degree to which you would be interested in receiving educational content on your mobile device.	.805
Q6	Your belief that accessing courses on your mobile device would be easy.	.722
Q10	Your belief that learning on mobile devices is the wave of the future.	.658
Q4	Your attitude to which the technology used for this instruction worked on your mobile device.	.640
Q2	Your attitude about instructors contacting you on your mobile device.	.550
Q5	Your belief that you have the technical skills to use your mobile device for learning.	.370

Extraction Method: Principal Axis Factoring.
[a]1 components extracted.

The two components were labeled and a mean attitudinal score was calculated for each factor. Factor 1 Post, student perceptions about their own use of mobile devices in education after instruction ($M = 3.00$, $SD = 0.98$). Gender was examined as an independent variable; Factor 1 post males ($N = 78$, $M = 3.11$, $SD = .92$), females ($N = 52$, $M = 2.76$, $SD = 1.00$). Homogeneity of variances was observed as assessed by Levene's test for equality of variances $F = .561$, $p = .455$. The results were not significant $F(3, 93) = .127$, $MSE = .130$, $p = .944$. A one-way ANOVA was conducted based on gender and

mean attitudes scores. There was a significant interaction between genders $F(1, 128) =$ 3.80, $MSE = .04$, $p = .04$.

Question 5 Post-instruction, *Your belief that you have the technical skills to use your mobile device for learning*, was of particular interest because it evaluated student self-confidence and self-belief regarding technical skills when using a mobile device. It did not fit with the other items in creating the factor and had the highest mean score ($N = 140$, $MS = 4.12$, SD .997). The overall self-belief score is high. Choen, Lee, Crooks, and Song (2012) developed a conceptual model about mobile learning readiness using the Theory of Planned Behavior with students in higher education. Using a series of videos about mobile learning, then surveying participants, they found that students who felt that m-learning was easy to use and useful were more likely to consider using their mobile devices for coursework (Choen et al., 2012). Different from the Choen et. al (2012) study, this study collected participant attitudes after an actual m-learning exercise, rather than just reviewing videos about m-learning.

A one-way between groups ANOVA was performed comparing all four groups. Homogeneity of variances was observed as assessed by Levene's test for equality of variances $F = 1.032$, $p = .382$. The results were not significant $F(3, 93) = .127$, $MSE = .130$, $p = .944$.

Before conducting an ANCOVA, the homogeneity-of-slopes assumption was tested. The interaction score for distribution of instruction and student attitudes about their technical skills was not significant $F(1, 93) = .90$, $MSE = 227.34$, $p = .35$, $\eta^2 = .01$. The interaction score for number of quizzes and student attitudes about their technical skills was not significant $F(1, 93) = .65$, $MSE = 143.92$, $p = .42$, $\eta^2 = .01$. The null

hypothesis that the population slopes are homogenous was not rejected and an ANCOVA was conducted.

A two-way ANCOVA examining the difference between the distribution of instruction and testing on final quiz scores controlling for student attitudes about their technical skills to use a mobile device for learning was conducted. There was a significant effect of testing on final quiz scores after controlling for student technical skills belief $F(1, 92) = 12.76$, $MSE = 2850.85$, $p = .00$, with the covariate accounting for about 12% of the variance of the number of tests on outcome scores, controlling for student attitudes about their technical skills, $\eta^2 = .12$.

Open-Ended Survey Responses. Forty-nine open-ended survey responses were collected. The responses are listed in Appendix H and were not codified or analyzed in this study. Some responses were referenced anecdotally in discussions.

CHAPTER 5

DISCUSSION

The purpose of this study was to investigate the effects of distributed presentation microlearning and the testing effect on mobile devices on learning outcomes in the form of quiz scores. This study also looked at student attitudes about the use of mobile devices for learning in higher education and their perceptions about their instructors' beliefs about mobile devices in higher education. The following section discusses the findings of each research question, survey results, limitations of the study, and implications for future research.

Findings by Research Question

Research Question 1. There is a relationship between delivery of instruction and learning outcomes.

In educational settings students sit for hours in classrooms or online listening to lectures. The massed presentation of information has been a foundation of instruction for centuries. This study explored effects of distributed presentation learning as compared to massed presentation learning.

The expected outcome, students receiving small units of instruction over a series of days would perform better than students receiving the instruction in a massed unit, on comprehensive quiz scores was not supported by the results. Initial results indicate there was no significant main effect of distribution of instruction in this study. This is contradictory to previous findings founded in educational theory (Ebbinghaus, 1913) as early as a century ago. Recent studies also support this finding and indicate that

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distribution of presentation of instruction (Raaijmakers, 2003; Raman et al. 2010; and Tulving et al., 1967) was more effective than massed presentation of instruction. Son and Simon (2012) found that across all ages and domains spacing instruction lead to better performance than massing instruction. Many of these studies relied on sets of paired words or sounds (Fishman et al., 1968; Peterson et al. 1962). This study departed from the traditional word-pair association distributed over a period of time and utilized a series of small instructional units called microlearning (Hug, 2005) as a replacement for a comprehensive lecture. Job and Ogalo (2012) found that microlearning could be used as a strategy to support learning and strengthen knowledge inputs.

The instruction in this study may have been too fragmented or short in duration without association to a larger learning goal to achieve the desired results. It may have simply been better to combine the micro units into a single learning intervention of approximately three to five minutes. One student replied in the open-ended survey: "I felt as though having multiple modules could be a slight nuisance. Once you got into the lesson, it was over. Forcing you to click out and back into another. I felt this made me lose my train of thought."

Research Question 2. There is a relationship between the number of assessments and learning outcomes.

As with hours-long lectures, students commonly take mid-term and final tests that may span hours of time. Not only is testing used to ascertain knowledge gained but it can also be used to reinforce learning. This study explored the testing effect in support of student learning as a form of practice or rehearsal.

In the two-way ANOVA, the main effect of testing produced no significant results. In a one-way ANOVA testing did produce significant results $F(1, 136) = 4.01$, $MSE = 1039.67$, $p = .047$. However, the expected outcome, participants receiving quizzes on individual units and a comprehensive quiz would perform better on the comprehensive quiz ($M = 68.71$, $SD = 17.05$) than the participants that only received the comprehensive quiz ($M = 74.23$, $SD = 15.17$), was not consistent with traditional research.

Rehearsal and practice were a key feature of the distributed presentation studies (Hintzman, 1971; Raman et al. 2010). One of the foundations for this study was a study by Johnson and Mayer (2009) in which participants were shown multimedia instruction and had either a) practice retention in the form of watching the instruction a second time, b) immediate rehearsal in the form of a quiz, or c) practice-transfer in the form of short answer questions. Additionally, the study found that participants in a delayed retention test remembered less than participants that took the immediate retention test (Johnson & Mayer, 2009). Other studies found similar results (Carrier et al. 1992; Karpicke et al., 2007). However, this study is also inconsistent with existing findings across all groups; distributed presentation instruction group with all quizzes ($M = 66.68$, SD 2.77) compared to the distributed presentation group with only the final quiz ($M = 74.92$, SD 2.69) and the massed presentation group with all quizzes ($M = 70.88$, SD 2.86) and the massed presentation group with only the final quiz ($M = 73.51$, $SD = 2.73$).

One possible explanation is that participants did not view the quizzes as an opportunity to reinforce learning. The study also had significant dropout rates. The dropout rates in the groups that had all quizzes were high after the first quiz. This may indicate that participants did not want to take the quizzes as part of the study. The study

may have been too similar to traditional schoolwork and therefore unenjoyable or burdensome. Another possible limitation is that students in the individual modules plus comprehensive quiz groups did not receive feedback on the individual quizzes and the quizzes did not become a learning intervention. However, Johnson and Mayer (2009) also did not provide feedback on answers in testing conditions.

Finally, Questions 1 and 2 were also examined in a factorial ANOVA with the added independent variable of gender (male, female). There were no significant results. Some of the groups were very small and analysis was not robust.

Research Question 3. There is a relationship between students' attitudes about using their personal mobile devices and a willingness to engage in learning on their devices.

Smartphone and mobile device ownership and usage among people aged 18–29 is virtually ubiquitous (Pew, 2017) and society's dependence on smartphones to access the internet exceeds even its' dependence on computers for accessing the internet (Bosomworth, 2015). This study used survey instruments to investigate participant attitudes about using personal mobile devices for learning. Student attitudes were moderately positive ($M = 3.19$, $SD = 0.90$) using Likert-type questions on a scale of 1 = Not at all well, to 5 = Extremely well. Two components emerged from the exploratory factor analysis of pre-instruction survey items. The first component related to students' perceptions about using their personal mobile devices for learning which indicated moderate to high positive loadings on five items.

This finding is consistent with Sung and Mayer (2013) who found that students' attitudes about using mobile media in an instructional study were significantly more positive than students using desktop computers.

Post-instruction participant survey attitudes were slightly less positive about the use of mobile devices for instruction ($M = 3.00$, $SD = 0.98$). A one-way ANOVA was conducted based on gender and mean attitudes scores for the post-instruction survey finding a significant interaction between genders $F(1, 128) = 4.128$, $MSE = 3.80$, $p = .04$. The groups were unequal, but the scores between genders, male ($N = 78$, $M = 3.11$, $SD = .92$) and females ($N = 52$, $M = 2.76$, $SD = 1.00$) indicate that males had a slightly more positive attitude about learning on mobile devices after instruction.

The post-instruction decrease in positive attitudes about using a personal mobile device for learning after instruction could be due to participants' dislike of the Blackboard mobile app. In an open-ended response one participant wrote, "My primary issue is Blackboard's software, which is generally bad." Another participant commented, "Blackboard has a horrible app."

Research Question 4. There is a relationship between students' beliefs about their technical abilities to use mobile devices and their willingness to engage in learning on mobile devices.

Although participants in the post-instruction survey showed a slight decrease in attitude about using mobile devices for learning, participant beliefs about their skills to use mobile devices was high ($N = 140$, $MS = 4.12$, $SD .997$) indicating strong self-confidence about technical skills. In their study about college students' intentions to use mobile devices for learning, Cheon et al. (2012) found that attitudes about perceived ease

of use and self-ability to use mobile devices contributed to a willingness to use mobile devices for learning.

A two-way ANCOVA examining the difference between distribution of instruction and testing on final quiz scores controlling for student attitudes about their own technical skills to use a mobile device for learning was conducted. There was a significant effect of testing on final quiz scores after controlling for student technical skills belief $F(1, 92) = 12.76$, $MSE = 2850.85$, $p = .00$, with the covariate accounting for about 12% of the variance of the number of tests on outcome scores, controlling for student attitudes about their technical skills, $\eta^2 = .12$. The effect size was small participants that took the instruction but did not take the final survey further reduced the sample size from the original participant group. No conclusive evidence can be stated.

Limitations

This study was conducted without direct physical contact between the researcher and participants utilizing the ASU Learning Management System, Blackboard. The version of Blackboard, 9.1, while mobile friendly, is not completely mobile native. While students at ASU are familiar with Blackboard for classes, using Blackboard for mobile was new to many participants. Other LMS tools may provide better mobile support and a more App-like experience.

Although student codes of ethics were expected to be adhered to, and participants had to sign acknowledgments of integrity, there is no way to guarantee that participants' respected the conditions and integrity of the study. As discussed, upon review of short answers, in at least one instance a participant copied content directly from a website. Outcome scores used as the dependent measure for analysis may have been compromised

by the ability of participants to use other resources to answer questions on the comprehensive quiz and therefore creating Type I error rates.

Study participants were very diverse representing all academic levels in higher education and virtually all majors. Participants were randomly assigned to multiple study dates so the study assumes no selection bias. There was a very high dropout rate of participants from time of enrollment to time of completion so the study did experience attrition. Athletes in recreational sports participating for community service hours had a higher rate of completion than other groups. It is possible that peer pressure among teammates or information sharing occurred, which could have created unreproducible outcomes for that particular group. However, only the total number of team members who completed the study was reported to the ASU student sports committee, not individual names, as guaranteed by the agreement of student anonymity in the IRB. Other participants may have been compelled to completed the study based on incentives in the form of extra credit or remuneration in the form of Amazon gift cards.

Other issues with dropouts were the inconsistent completion of all components. The unevenness of completion of pre-survey, instruction and quizzes, and post-survey decreased thorough analysis of participants across all study components.

Another limitation of the study was potential technical difficulties experienced by some participants. One group started the study on a day when a system-wide Blackboard outage occurred. Other participants reported various technical difficulties such as the Blackboard app hanging or not responding. Since participants used their own personal devices for the study, it is not known if various devices utilized the most current available operating systems or how much memory was available for the Blackboard app.

The study had an additional limitation based on the number of quizzes received by some participants. Approximately half the participants received five additional quizzes to evaluate the testing effect. The scores on the additional quizzes were not included in the study results and feedback about the quizzes was not provided.

Potential limitations of significant results found for testing in a one-way ANOVA $F(1, 136) = 4.01$, $MSE = 1039.67$, $p = .047$, include internal threats to validity in the type of instrument used for testing and the ability of participants to utilize outside resources for answering quiz questions.

Potential limitations of significant results found for student attitude scores in one-way ANOVA between genders $F(1, 128) = 4.128$, $MSE = 3.80$, $p = .04$, include unequal sample sizes and a small effect size.

Implications

According to the study results, distributed presentation microlearning and the testing effect on mobile devices were not significant on learning outcomes scores. This differs from many other studies about distributed presentation learning (Craik, F.I.M, 1970; Gates, 1917; Melton, 1970; Raaijmakers, 2003) and the testing effect (Carrier et al. 1992; Johnson et al., 2009; Karpicke et al, 2007). Implications for instruction may be that the current method of massed instruction is appropriate for higher education and for the dissemination of complex concepts. The use of a mobile device could be a confounding effect in this study.

The results regarding student attitudes and usage of their personal mobile devices for learning are in line with findings by Chen and deNoyelles (2013) and Sung and Mayer (2013) but indicate a continued increase in positive attitudes and intentions that

students are receptive to using personal mobile devices for learning (Al-Emran et al., 2016; Jeno et al., 2017; Yeap et al., 2016). While intention and action are different, the implications for educators is that making learning content available for consumption on personal mobile devices would be well received by students.

Development of Custom Content

This study utilized the development of custom content formatted to resemble an app-like experience. The method is similar to the Micro Unit content created by Beutner and Pechuel (2017) in their OPALESCE study. The development of this content required multiple skills including: compression technology, design, illustration, interactive web forms, mobile user experience and interaction theory, and narration and video creation.

First, each unit was storyboarded using PowerPoint, the narration was noted for each slide in the notes section. Next, backgrounds, illustrations, and text screens were created using Adobe Illustrator. Graphics were set up in portrait format, which is different than the traditional video format which is landscape. A screen size of 480 pixels tall x 320 pixels wide was selected to simulate an aspect ratio of 3:2. This screen resolution is standard in older devices and lower than most current smartphone devices, but preliminary tests of higher resolution content at 960 pixels tall x 640 pixels wide resulted in large file sizes of more than 3mb. To prevent buffering files were compressed and saved to be approximately 1mb or smaller. Each illustration and text screen was saved as a .jpg format. The images were imported to Camtasia where they were paired with narration to create a video. In Camtasia, the canvas size was adjusted from the default format of 1280 pixels wide x 720 pixels tall or 720p HD to 480 pixels tall x 320 pixels wide (portrait). Once the illustrations and narration were synched in Camtasia the

content was split into units of approximately 30 s – 1 min and exported as an MP4 file format with medium compression for smaller file sizes. The MP4 files were then loaded into Blackboard using exiting tools to add videos to Blackboard content. The Blackboard video player automatically adds minimal video controls to each video.

These skills are unique and may not be in the repertoire of most instructors or even instructional designers. Carlson and Gadio (2002) found that while most instructors want to integrate technology into teaching, they lack the time and technical skill to do so. Creating professional development programs such as McKenny, Boschman, Pieters, and Voogt's (2016) Teacher Talk: Collaborative Design of Technology-Enhanced Learning, is essential to improve teacher technical fluency and skills.

As newer smartphones are developed and released other considerations, including smartphone screen sizes and resolution will be critical. Smartphones exponentially exceed computational perform of not distant desktop and laptop computers so more sophisticated graphics, interactions, and videos should be created to take advantage of smartphone features. Expansion of free and easily accessible wifi will improve content load times when no wifi connection is available and will minimize some necessity to over compress visual content. To realize the potential of learning on smartphones, a team of experts is needed to assist instructors with technical training skills and in the creation and deployment of mobile ready content.

Future Research

Like e-learning in the late 1990's, mobile learning or m-learning is emerging as a new area of study. Instruction in higher education does not yet take advantage of the affordances of mobile devices to promote learning. Many instructors may not have the

technical skills and therefore need training and support for content creation specifically

for mobile devices. Further, more research is needed to develop best practices for the type

of content suitable for learning on personal mobile devices. To utilize the affordances of

mobile devices in education additional studies about testing and user content creation

such as short-answers, possible homework assignments and collaboration with other

students to support learning should be investigated. Future research about human

interactions with mobile devices (Billinghurst et al., 2015; Hobber, 2013) for learning is

needed and should include studies about the format and presentation of content. New

paradigms may need to be developed moving content away from traditional landscape

video formats mimicking vertical App-like formats.

Conclusion

Smartphones and mobile devices of today are more powerful than many

computers of the previous decade. Mobile devices have permeated our society and are

replacing traditional laptops and desktops for the way we communicate, interact socially,

access the internet and conduct our daily activities. This study indicates that students are

skilled with their mobile devices and are receptive to using them for higher education or

are already using them to capture lecture notes, images of instruction written on black-

and whiteboards, and reminders for class. Some participants responded positively to

receiving instructional content on their mobile devices. It is now up to educational

institutions to take the next step in effectively integrating mobile devices and instruction

optimized for mobile devices in education.

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APPENDIX A

CONSENT FORM

Learning on Mobile devices consent form
Microlearning with Mobile Devices: Effects of Distributed Presentation and the Testing Effect

About this project
Thank you for your interest in this research project. The expected effort for this research project is approximately 30-45 minutes total, over the course of five weekdays, approximately 5-7 minutes per day, starting on Monday and ending on Friday.

The research project consists of these components:
1. A pre-instructional survey - 26 questions
2. 5 audio/video modules of learning content. Each module consists of 4 – 6 microlearning episodes of approximately 30 seconds to one minute in length.
3. Accompanying quizzes.
4. Final quiz, 10 question.
5. Final survey, 10 questions.

What you will need to participate in this study
1. An Android or Apple iOS smartphone. This research project is specifically designed to be completed entirely on a smartphone.
2. The Blackboard App available through Apple iTunes or Google Play.
3. An ASU email address.
4. A wifi connection.

Letter of consent

Dear Participant,

My name is Elaine Rettger, I am a doctoral candidate in the Educational Technology and Instructional Design program in the Mary Lou Fulton College of Education at Arizona State University.

You must be 18 years of age or older to participate, and have access to a smartphone. You will be asked to download the Blackboard app to your phone.

The purpose of this research project is to investigate learning and testing on smartphones in an effort to improve educational support, curriculum development and best practices for using smartphones in higher education.

You will receive five distributed presentation micro learning modules over a one-week period. Each module will be accompanied by a quiz. You will receive a final quiz covering the content of all modules after the last module is completed. You will also be asked to fill out a pre- and post- survey.

Your participation will take approximately 30-45 minutes total, to complete. You are free to decide whether you wish to participate in this study. If you start the study but change your mind you are free to leave the research at any time without consequence.

I cannot promise any benefits to you or others from your taking part in this research. However, possible benefits include improved understanding of smartphones in education and policies that could benefit future students as a result of information gathered in this research project.

Your responses will be confidential. Quiz results from the application and your responses to the surveys will be collected for data analysis. All information will be collected through the ASU Blackboard Learning Management System. All data will be stored on a secure computer. You will be assigned a randomized ID, and any personal identifying information will be stripped from the data collected. The results of this study may be used in reports, presentations or publications but your name and personal information will not be used.

If you have any questions or concerns about this study or your participation in this study, please call me at 480-965-7906 or email me at Elaine.Rettger@asu.edu or the Principal Investigator at Dr. Gary Bitter Bitter@asu.edu.

This research has been reviewed and approved by the Social Behavioral IRB, STUDY00003713. You may talk to them at 480-965-6788 or by email at research.integrity@asu.edu if:

- Your questions, concerns, or complaints are not being answered by the research team.
- You cannot reach the research team.
- You want to talk to someone besides the research team.
- You have questions about your rights as a research participant.
- You want to get information or provide input about this research.

By agreeing to this study, you agree to only use the instruction and resources found in the content area provided. No outside sources such as the google, bing or other websites, should be used for completion of instruction and quizzes in this study.

Sincerely,

Elaine Rettger

Please enter your full name

_____

If you are a member of an ASU Sport team, please indicate your team affiliation so that your team receives credit for your participation.

_____

If you are participating for extra credit, please indicate your professor's name.

_____

Thank you for completing the consent form. Please take the pre-instructional survey and be prepared to begin the study.

APPENDIX B

BLACKBOARD LMS DAILY ANNOUNCEMENTS TO PARTICIPANTS

Sample morning announcement for participants in the distributed presentation groups, sent at 8:00 a.m.

Please be sure to complete Module 1 and the Module 1 quiz before midnight. If you have already completed the module and quiz, please disregard this message.

Thank you for participating in this research study.

Please take the pre-instruction survey. https://goo.gl/zttU42

The survey is one of the required components of the study.

All instruction and quizzes are designed to be viewed and completed on a smartphone. Please only use your smartphone for this research project. You may experience some brief buffering or delays when first accessing the content. Your patience is appreciated.

This study consists of the following components:

1. Blackboard mobile – available on iTunes and Google Play, you must download the app to access this study. Please sign-in with your ASUrite ID and password. View this **google doc** https://goo.gl/zttU42 for detailed instructions.

2. 25 question pre-instruction survey

3. Daily announcements regarding availability of instructional content

4. 5 modules of instructional content lasting between 3–5 minutes with a 5 question quiz for each module. Blackboard course content logs will be compared to ensure participation.

5. 1 final, 10 question quiz

6. Post-instruction survey

7. Instruction and quizzes cannot be reopened after day/date of distribution

Sample evening announcement for participants in the distributed presentation groups sent at 6:00 p.m.

Please be sure to complete Module 1 and the Module 1 quiz before midnight. If you have already completed the module and quiz, please disregard this message.

Thank you for participating in this research study.

Sample daily announcement for participants in the massed distributed presentations send daily at 8:00 a.m.

Thank you for participating in this research study.

Please take the pre-instruction survey. https://goo.gl/zttU42
The survey is one of the required components of the study.

All instruction and quizzes are designed to be viewed and completed on a smartphone. Please only use your smartphone for this research project. You may experience some brief buffering or delays when first accessing the content. Your patience is appreciated.

All modules, module quizzes and the final quiz must be completed by midnight, Friday.

This study consists of the following components:

1. Blackboard mobile – available on iTunes and Google Play, you must download the app to access this study. Please sign-in with your ASUrite ID and password. View this **google doc** https://goo.gl/zttU42 for detailed instructions.

2. 25 question pre-instruction survey

3. Daily announcements regarding availability of instructional content

4. 5 modules of instructional content lasting between 3–5 minutes with a 5 question quiz for each module. Blackboard course content logs will be compared to ensure participation.

5. 1 final, 10 question quiz

6. Post-instruction survey

7. Instruction and quizzes cannot be reopened after midnight, Friday.

APPENDIX C

TECHNICAL JOB AID FOR THE BLACKBOARD APP

Dear student,

Thank you for your interest in participating in my research project. You will receive five modules about lightning. The modules are audio and video and are designed to be viewed exclusively on your smartphone. **Please use headphones or turn on your speakers. Please respect the conditions of this study and only view and complete the learning content and quizzes on your smartphone.**

This study has been tested with a pilot group and the content performs on both Android and iOS devices. This study has not been tested on a Windows phone.

Participants will be enrolled in one of four different conditions. All content is the same across conditions. Each study group starts on a Monday and ends on a Friday.

Study consists of:

1. A **consent form**. https://goo.gl/g5ZPrg You must be 18 years of age or older to participate.

2. A **pre-instruction survey.** https://goo.gl/k5rzVN

3. Blackboard daily announcements letting students know that they are participating in a study and that information is available.

4. Instructional modules daily; approximately 3 – 5 minutes of audio and video content about lightning.
   You will need to plug in your headphones, the audio does not work well with bluetooth headphones.

5. A quiz after each module; 5 questions

6. A final quiz; 10 questions

7. A **final survey**. https://goo.gl/nJc74h

Please attempt to answer questions to the best of your ability and answer all questions without accessing other resources, such as the internet.

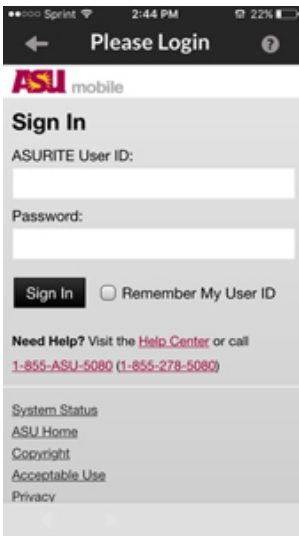Students will need a wifi connection and the Blackboard app.

Below are screen captures and instructions about how to participate.
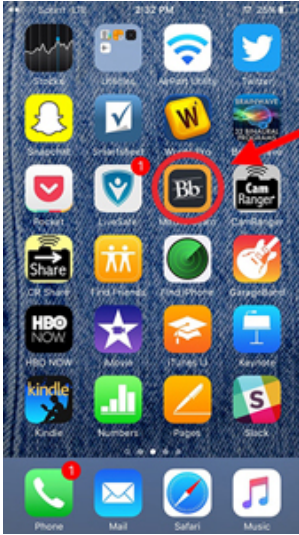
1.

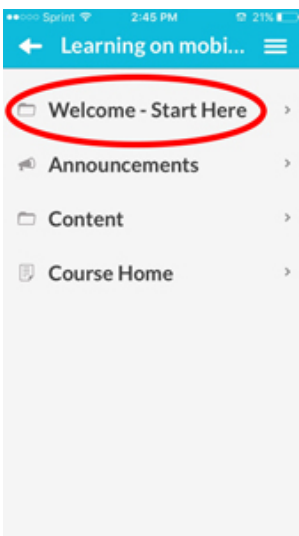**Get the Blackboard app free at iTunes or Google play**
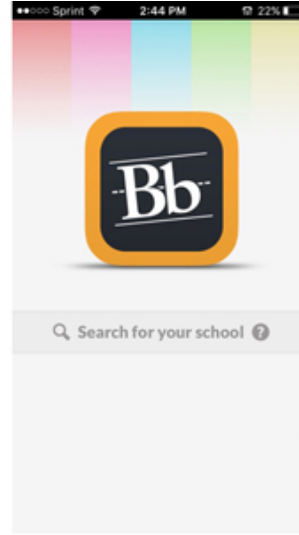
2.

Enter Arizona State University in the school search

Q Search for your school

3.

Sign in with your ASURITE user ID and password, the same ID and password you use for My ASU

Please Login

ASU mobile

Sign In

ASURITE User ID:

Password:

Sign In   ☐ Remember My User ID

Need Help? Visit the Help Center or call
1-855-ASU-5080 (1-855-278-5080)

System Status
ASU Home
Copyright
Acceptable Use
Privacy

4.

All your classes in Blackboard will show on the menu, you may need to scroll down to find the project

Menu   ✎ Edit

Learning on mobile devices   ›

⚙ Settings   ❓ Help

5.

Welcome area contains link to survey

← Learning on mobi... ☰

☐ Welcome - Start Here   ›

📢 Announcements   ›

☐ Content   ›

📄 Course Home   ›
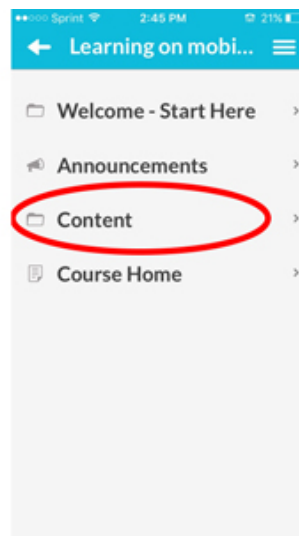
6.

Content area contains all videos and quizzes please have speakers or headphones enabled

← Learning on mobi... ☰

☐ Welcome - Start Here   ›

📢 Announcements   ›

☐ Content   ›

📄 Course Home   ›
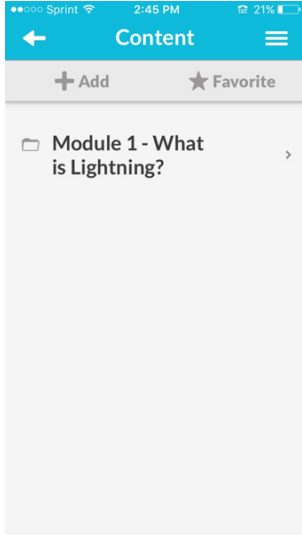
7.

Modules contain very short learning content

Content

✚ Add   ★ Favorite

📁 Module 1 - What is Lightning?   ›
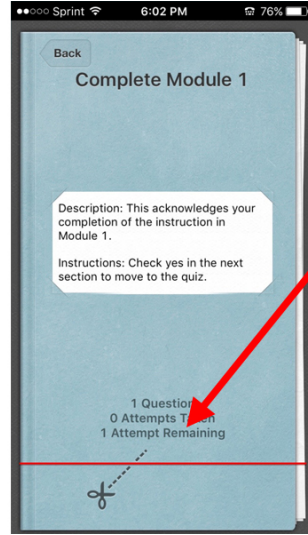
8.

Please swipe the string to access quizzes and/or acknowledge that you have completed content

Back

Complete Module 1

Description: This acknowledges your completion of the instruction in Module 1.

Instructions: Check yes in the next section to move to the quiz.

1 Question
0 Attempts Taken
1 Attempt Remaining

APPENDIX D

PRE-SURVEY QUESTIONNAIRE

Thank you for participating in this survey. All survey data will be stripped of any identification after surveys are matched with completed experiments. Participant information is collected only so that participants can receive credit or community service hours. All identification will also be removed from all experimental conditions. For the purpose of this survey a mobile device is considered a smartphone or tablet. This survey consists of 25 questions; 10 demographic questions and 15 attitudinal questions. The entire survey will take approximately 5–7 minutes to complete.

Demographic questions

1. Please indicate your age
   a. 18–20
   b. 21–24
   c. 25–30
   d. 25–30
2. Please indicate current academic status
   a. Freshman
   b. Sophomore
   c. Junior
   d. Senior
   e. Graduate student
3. Please indicate which type of smartphone or mobile device (tablet) you own – select all that apply.
   a. Apple iOS
   b. Android
   c. Windows
   d. Blackberry
4. How many mobile devices (smartphone and/or tablet) how many do you own? E.g., smartphone and tablet = 2
   a. 2
   b. 3
   c. 4
   d. 5 or more
5. Approximately how many hours per-day do you use your mobile device(s)
   a. Less than 1
   b. 1–3
   c. 4–5
   d. 6–7
   e. more than 7
6. If you also have a desktop or laptop computer, please indicate how many?
   a. 1
   b. 2
   c. 3
   d. 4 or more

7. How many hours per-day do you use your desktop or laptop computer(s) separate from your mobile device usage?
    a. 1
    b. 2–3
    c. 4–5
    d. 6 or more
8. In how many of your classes at ASU have instructors sent classroom information, alerts, announcements or notifications to your mobile device(s)?
    a. None
    b. 1–3
    c. 4–5
    d. 6–7
    e. 8 or more
9. Do you use a mobile device to support learning during class? E.g., to record lectures, take notes, or photos of classroom materials that your instructor writes on a black- or whiteboard?
    a. Yes
    b. No
10. If you indicated yes to question 9, how often do you use your mobile device to support learning in class?
    a. A couple of times per month
    b. Once per week
    c. A few times per week
    d. Daily
11. Please indicate your gender
    a. Female
    b. Male
    c. Prefer not to say
12. Please indicate your current area of study
    a. Open-ended

Attitudinal questions

Attitudes about learning on mobile devices

Adapted from: An investigation of mobile learning readiness in higher education based on the theory of planned behavior. Cheon, J., Lee, S., Crooks, S. M., & Song, J. (2012).

1. I would be interested in receiving educational content on my mobile device.
    a. Not at all
    b. Once or twice per semester
    c. Once per month
    d. Weekly
    e. I would like to receive all my instruction on my mobile device.
2. It is acceptable for instructors to contact me with class related information, announcements, alerts and reminders about assignments on my personal mobile device.

a. No, it's private, I do not want my instructors contacting me on my mobile device at all
b. Once or twice per semester
c. I would like monthly communication from my instructor about assignments and classroom updates
d. I would like my instructor to contact me weekly with classroom updates
e. My instructors are free to contact me anytime on my mobile device

3. I think learning on a mobile device can meet the needs of my current instruction.
   a. Not at all well
   b. Slightly well
   c. Moderately well
   d. Very well
   e. Extremely well

4. I think mobile devices could improve my ability to learn.
   a. Not at all well
   b. Slightly well
   c. Moderately well
   d. Very well
   e. Extremely well

5. I think mobile devices can help me stay on-top of assignments and instruction.
   a. Not at all well
   b. Slightly well
   c. Moderately well
   d. Very well
   e. Extremely well

6. I think mobile devices could help me get my assignments completed more quickly.
   a. Not at all well
   b. Slightly well
   c. Moderately well
   d. Very well
   e. Extremely well

7. I think I can use my mobile device to learn all my course content.
   a. Not at all well
   b. Slightly well
   c. Moderately well
   d. Very well
   e. Extremely well

8. I would like my coursework more if it included more mobile learning.
   a. Not at all well
   b. Slightly well
   c. Moderately well
   d. Very well
   e. Extremely well

9. Using mobile learning in my coursework would be a pleasant experience.
   a. Not at all pleasant

b. Slightly pleasant
   c. Moderately pleasant
   d. Very pleasant
   e. Extremely
10. Including mobile learning in coursework is a good idea.
   a. Not at all
   b. Slightly good idea
   c. Moderately good idea
   d. A good idea
   e. Extremely good idea
11. I think my instructors possess adequate technical skills to use mobile devices effectively in the presentation and preparation of course content.
   a. Not at all well
   b. Slightly well
   c. Moderately well
   d. Very well
   e. Extremely well
12. I think my instructors possess adequate technical skills to use mobile devices effectively for quizzes and creating homework assignments.
   a. Not at all
   b. Slightly well
   c. Moderately well
   d. Very well
   e. Extremely well
13. I think my instructors would be in favor of utilizing mobile learning in their courses.
   a. Not at all
   b. Slightly well
   c. Moderately well
   d. Very well
   e. Extremely well
14. I think my fellow students would be in favor of utilizing mobile learning in their coursework.
   a. Not at all well
   b. Slightly well
   c. Moderately well
   d. Very well
   e. Extremely well
15. I think my instructors believe that a mobile device could be a useful educational tool in their coursework.
   a. Not at all
   b. Slightly well
   c. Moderately well
   d. Very well
   e. Extremely well

APPENDIX E

TEXT PASSAGES AND SAMPLE SCREENS FOR MICROLEARNING

MOBILE MODULES

Lightning Instruction Modules

Approximately 5-minutes in length with 4-5 question quiz for each module.

Average narration of approximately 100 words per minute for instruction. Each module consists of 300 – 500 words.

Introduction:
Narrative:
       Thank you for participating in this study about learning on mobile devices. Your input will be valuable to the development of mobile learning content and creation and may provide new opportunities for instruction in academic settings.

Module 1 – Lightning overview
Narrative:
       Let's talk about lightning.

       Lightning is one of the oldest observed natural phenomena on earth, but it is also one of the most misunderstood. Simply put, lightning is a spark of electricity in the atmosphere between clouds, the air, or the ground. Lightning can be seen in volcanic eruptions, extremely intense forest fires, surface nuclear detonations, heavy snowstorms, in large hurricanes, and of course, in thunderstorms.

       A thunderstorm is defined as convection that has at least one stroke of lightning that produces audible thunder.

       At any given time there may be as many as 2,000 thunderstorms occurring across the earth. NASA satellite research indicates that these storms produce lightning flashes about 40 times per second, worldwide. This translates to more than 14.5 million storms and 1.4 billion lightning flashes each year. The National Weather Service estimates that lightning strikes the ground more than 25 million times each year in the United States.

       Although lightning is the second highest cause of weather-related deaths in the US, fortunately on average, there are only about 50 lightning fatalities per year, in the United States. The chance of an average person in the US being struck by lightning in a given year is estimated at 1 in 960,000.

       Lightning strikes can injure humans in several different ways:

Direct

- o Direct strike – the person is part of the flash channel. Enormous quantities of energy pass through the body very quickly and this can result in internal burns and organ damage, explosions of flesh and bone, and a damaged nervous system. Depending on the flash strength and access to medical services, it may be instantaneously fatal or cause permanent injuries and impairments.

- o Contact injury – the person was touching an object, generally a conductor, that is electrified by the strike.

- Side splash – branches form "jumping" from the primary flash channel, electrifying the person.

- Blast injuries – being thrown and suffering blunt force trauma from the shock wave (if very close) and possible hearing damage from the thunder.

2. **Indirect**

- Ground current or "step potential" – Earth surface charges race towards the flash channel during discharge. The ground is not a good conductor of electricity, it impedes and resists the electrical current produced by the lightning strike, but because of the high impedance of the ground, the current "chooses" a better conductor, often a person's legs, passing through the body. The near instantaneous rate of discharge causes a potential (difference) over distance, which may amount to several thousand volts per linear foot. This phenomenon is responsible for more injuries and deaths than the above three combined. Reports of "Tens of cows killed by a lightning strike..." are classic examples.

- EMPs – the discharge process produces an electromagnetic pulse (EMP) which may damage an artificial pacemaker, or otherwise affect normal biological processes.

3. **Secondary or resultant**

- Explosions
- Fires
- Accidents

Thank you for listening to Module 1, please take the quiz at the end and move on to Module 2.

Learning on Mobile Devices

Please turn on your smartphone speakers

What is Lightning?

Volcanic eruptions

Intense forest fires

Heavy snowstorm

Large hurricanes

Lightning is a spark of electricity in the atmosphere between clouds, the air or the ground.

Direct strike

Direct strike contact injury

Indirect strike

Secondary or resultant strike

End of Module 1

Module 2 – Thunderstorm Formation
Narrative:

Welcome to Module 2. Module 2 discusses the necessary ingredients for the formation of thunderstorms and lightning.

Thunderstorms provide the environment needed for lighting. Thunderstorms are very unstable systems. When a thunderstorm is created updrafts and downdrafts of air occur regularly and within close proximity. All thunderstorms require three ingredients for their formation:

- Moisture
- Instability, and
- A lifting mechanism

Moisture

Moisture in the atmosphere comes from large bodies of water such as the ocean or gulfs. The temperature of the water is also a factor in how much moisture is in the atmosphere. Evaporation is higher in warm ocean currents and therefore more moisture is released into the atmosphere. The warm Atlantic Ocean currents off the southeastern U.S. produce more moisture than the cool Pacific Ocean currents off the southwestern coast near Southern California. This helps explain why there is more rain in Florida than Southern California.

Instability

To be unstable air must continue to rise if pushed upwards or continue sink if pushed downwards. Unstable air masses have warm moist air near the earth's surface and cold dry air above. If warm moist air continues to rise it will cool and some of the water vapor will condense forming clouds that are thunderstorms.

Lift

The third element for thunderstorm creation is lift. Lift is the mechanism that moves air upward or downward. Lift is created from different air densities interacting. Warmer less dense air rises and cooler denser air sinks. Some of the sun's heating of the earth's surface is transferred to the air creating different air densities. Things that can cause differences in the warming of air are:

1. Landmasses
2. Bodies of water that tend to heat slower than landmasses
3. Dark surfaces like pavement also cause a difference in the warming of air, dark surfaces absorb more light – since light is energy, the light absorbed by dark surfaces is emitted as heat

Thank you for listening to Module 2, please take the quiz at the end and move on to Module 3.
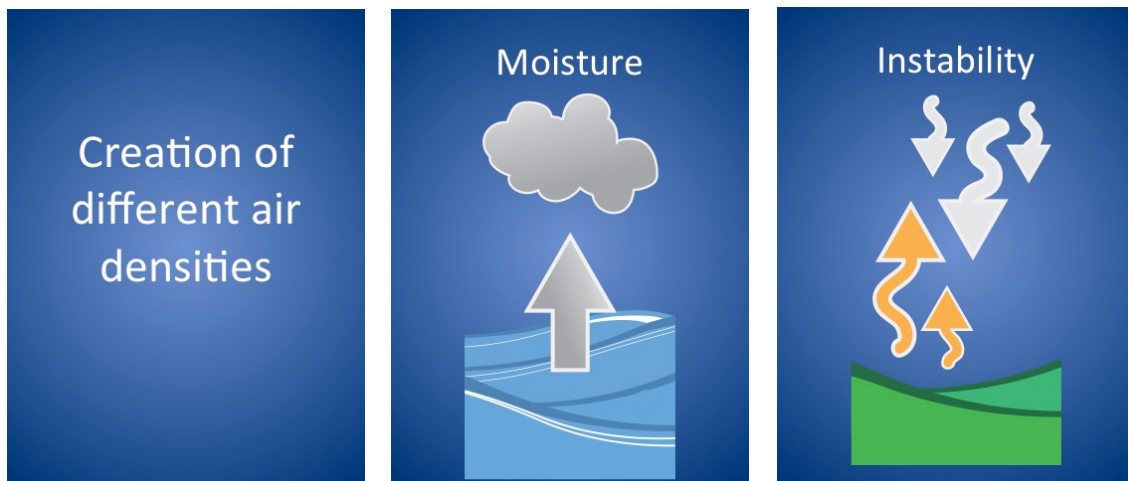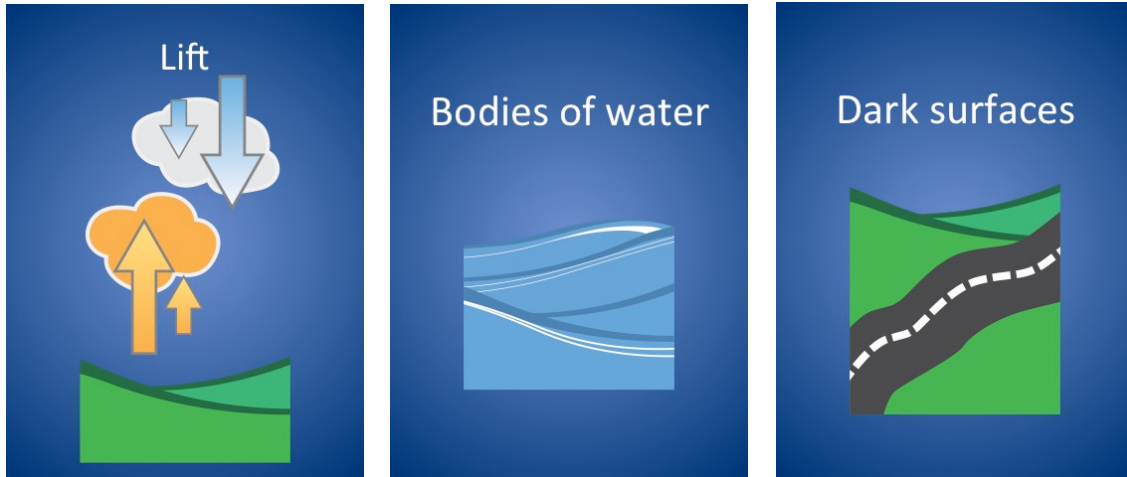
Module 3 – How lightning is formed in thunderstorms
Narrative:

Welcome to Module 3. Module 3 discusses lightning formation in thunderstorms.

As the ice particles within a cloud (called hydrometeors) grow and interact they collide, fracture and break apart forming lightning. It is thought that the smaller particles tend to acquire positive charge, while the larger particles acquire more negative charge.

The smaller positively charged particles tend to rise while the larger negatively charged particles gravitate toward the bottom of clouds.

These particles tend to separate under the influences of updrafts and gravity until the upper portion of the cloud acquires a net positive charge and the lower portion of the cloud becomes negatively charged.

This separation of charge produces enormous electrical potential both within the cloud and between the cloud and ground. This can amount to millions of volts, and eventually the electrical resistance in the air breaks down and a flash begins. Lightning, then, sudden electrostatic discharge between positive and negative regions of a thunderstorm.

A lightning flash is composed of a series of strokes with an average of about four strokes per flash. The length and duration of each lightning stroke vary, but typically average about 30 microseconds. (The average peak power per stroke is about 10^{12} watts.)

The charged regions in the atmosphere temporarily equalize themselves through this discharge referred to as a strike. The discharge is considered a strike if it hits an object on the ground.

Although lightning is always accompanied by the sound of thunder, distant lightning may be seen but be too far away for the thunder to be heard.

Lightning does not always escape to the ground. Lighting can form

- intra-cloud lightning or IC which is lightning that stays within the cloud,
- cloud to cloud lightning or CC which is lightning between two clouds,

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- or between a cloud and the ground (CG lightning).

Lightning is not distributed evenly around the globe. About 70% of lightning occurs over land in the tropics where atmospheric convection is the greatest.

Thank you for listening to Module 3, please take the quiz at the end and move on to Module 4.
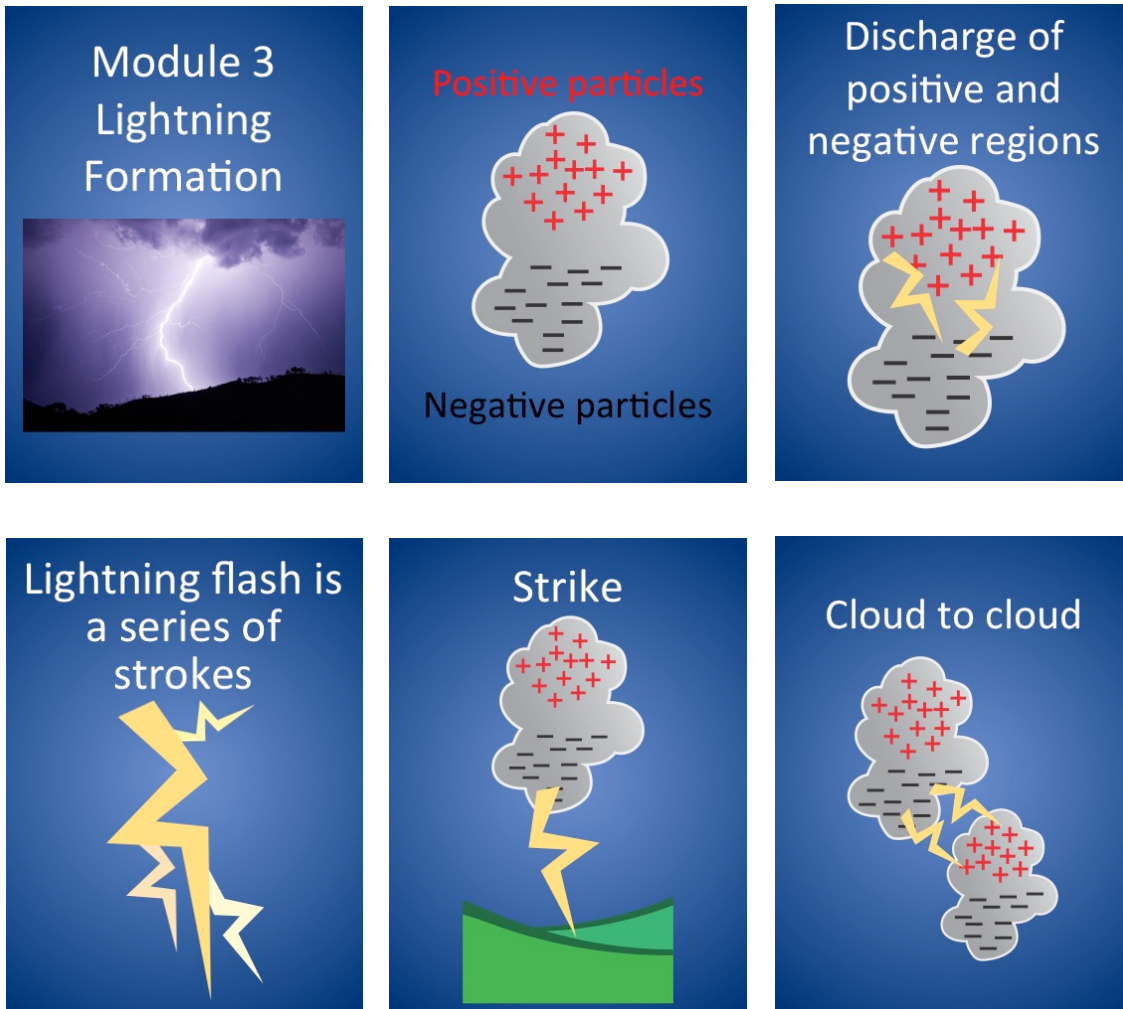
Module 4 - The Most Common Types of Lightning
Narrative:
Welcome to Module 4. Module 4 discusses the most common types of lightning. As mentioned at the end of Module 3, there are different types of lightning.

Intra-cloud lightning is the most common type of lightning discharge. Intra-cloud lightning occurs between oppositely charged centers within the same cloud and can jump between different charge regions. Usually the process takes place within the cloud and looks from the outside of the cloud like a diffuse brightening which flickers. However, the flash may exit the boundary of the cloud and a bright channel, similar to a

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cloud-to-ground flash, can be visible for many miles. Intra-cloud lightning is sometimes called sheet lightning because it appears to light up the sky with a sheet of light.

Cloud to cloud lightning occurs between two or more separate clouds and is also referred to as inter-cloud lightning. Lightning strikes will never reach the ground but can pose safety risks for aircraft. Cloud to cloud and intra-cloud lightning occurs approximately 10 times more often than cloud to ground lightning.

Cloud to air lightning occurs when a lightning discharge jumps from the cloud to clear air. Cloud to air lightning is caused by oppositely charged air and cloud regions interacting.

Cloud-to-ground lightning is the most damaging and dangerous form of lightning. Most flashes originate near the lower-negative charge center and deliver negative charge to the Earth. Although cloud-to-ground lightning is not the most common type of lightning, it is the one which is best understood because the lightning strike terminates with a physical object, the earth, and can therefore be measured by instruments.

Positive cloud-to-ground strikes carry a positive charge to Earth. Positive strikes make up less than 5% of all lightning strikes, but these strikes can be far more dangerous because they are more highly charged than negative lightning and the discharge current can last longer. A positive lightning strike can be as many as a billion volts – about 10 times that of negative lightning.

Inter-cloud lightning, as the name implies, occurs between charge centers in two different clouds with the discharge bridging a gap of clear air between them.

Other Types of Lightning
There are many types and forms of lightning. Some are lightning subcategories, and others may arise from optical illusions, appearances, or myths. Some popular terms include: *ball lightning, heat lightning, sheet lightning, red sprites, blue jets, and elves.*

Thank you for listening to Module 4, please take the quiz at the end and move on to Module 5.
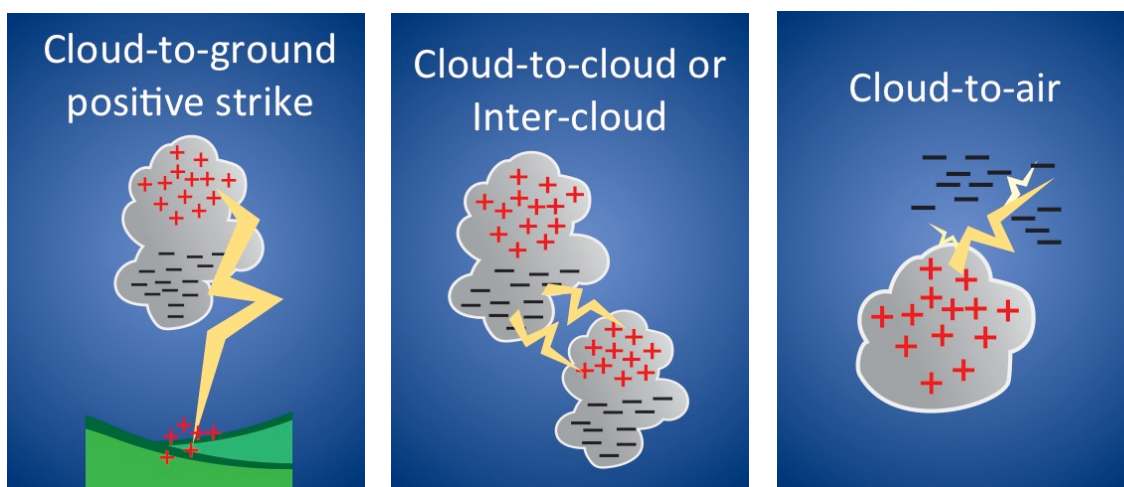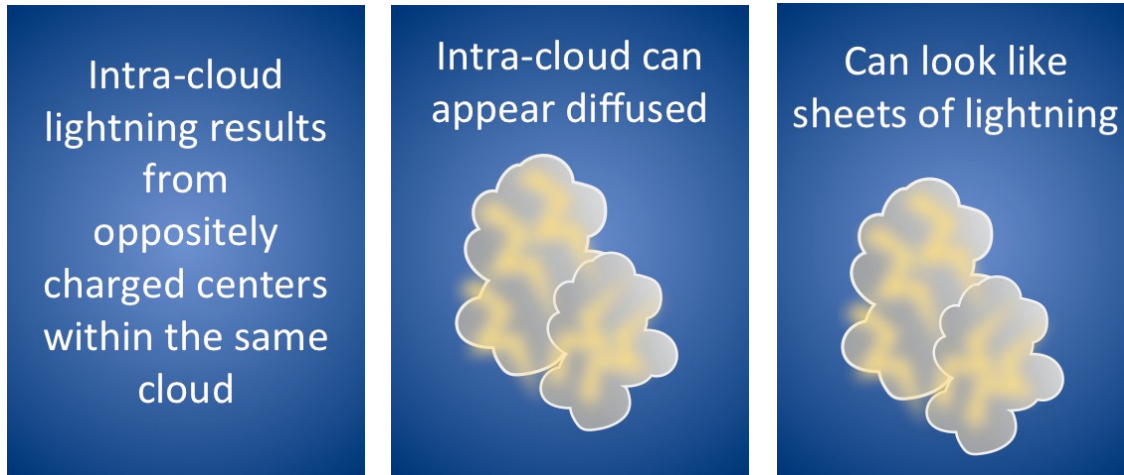
Module 5 – Heat Lightning

Narrative:

The term "heat" in heat lighting has little to do with temperature. Since heat lightning is most likely to be seen in association with air mass thunderstorms in the warm season, the term "heat" may have been used because these flashes are often seen when surface temperatures are warm.

The air near a lightning strike is heated to 50,000 degrees Fahrenheit, which is hotter than the surface of the sun. Rapid heating and cooling of air near the lightning channel causes a shock wave that results in thunder.

Thunder from a nearby lightning strike will have a very sharp crack or loud bang.

Thunder from a distant strike will have a continuous rumble.

If a lightning strike is a sufficient distance from an observer, sound from the strike will not be heard. These silent bolts are called heat lightning. Lightning bolts produce thunder, but the thunder sound does not travel all the way to the observer if the observer is too far away.

The movement of sound in the atmosphere depends on the atmospheric properties of the air such as temperature and density. Because temperature and density change with height, the sound of thunder is refracted through the troposphere – the lowest layer of Earth's atmosphere. This refraction results in spaces of volume in which the thunder does not propagate through.

The sound of thunder often reflects off the earth's surface. The rumbling sound from thunder is partly due to reflections off the earth's surface. This reflection and refraction leaves voids where thunder cannot be heard.

The earth's curvature also contributes to people far from the strike from not hearing it. Thunder is more likely to be bounced off the earth's surface before it reaches an observer far from the strike. With this said, the right refraction and reflection can result in people on the earth's surface being able to hear thunder at very far distances from

the storm. The reflection and refraction in the troposphere determines who hears the strike and who doesn't.

Thank you for listening to Module 5, please take the comprehensive quiz and the exit survey.

Heat lightning has little to do with temperature

Shock waves near the lightning channel create thunder

Strikes far from an observer are not always heard

The sound of thunder is refracted through the troposphere

Sound often reflects off the earth's surface

With heat lightning the sound of thunder is not heard

APPENDIX F

POST-INSTRUCTION SURVEY

Learning on Mobile devices

Thank you for participating in the Learning on Mobile devices study. This survey consists of 10 questions and will take approximately 3–5 minutes to complete.

Now that you have received some instruction on your mobile device, please indicate:

1. The degree to which you would be interested in receiving educational content on your mobile device.
   a. Not at all
   b. Once or twice per month
   c. Once per month
   d. Weekly
   e. I would like to receive all my instruction on my mobile device
2. Your attitude about instructors contacting you on your mobile device.
   a. No, it's private, I do not want my instructors contacting me on my mobile device at all
   b. Once or twice per semester
   c. I would like monthly communication from my instructor about assignments and classroom updates
   d. I would like my instructor to contact me weekly with classroom updates
   e. My instructors are free to contact me anytime on my mobile device
3. Your attitude about how well do you think learning on a mobile device can meet your instructional needs.
   a. Not at all well
   b. Slightly well
   c. Moderately well
   d. Very well
   e. Extremely well
4. Your attitude to which the technology used for this instruction worked on your mobile device.
   a. Did not work well
   b. Worked slightly well
   c. Worked moderately well
   d. Worked very well
   e. Worked extremely well
5. Your belief that you have the technical skills to use your mobile device for learning.
   a. Not at all well
   b. Slightly well
   c. Moderately well
   d. Very well
   e. Extremely well
6. Your belief that accessing courses on your mobile device would be easy.
   a. Not at all well
   b. Slightly well

    c. Moderately well
    d. Very well
    e. Extremely well

7. Your belief that you would have more learning opportunities if your coursework were available on mobile devices.
    a. Not at all
    b. Slightly more opportunities
    c. Moderately more opportunities
    d. More opportunities
    e. A lot more opportunities

8. Your belief that you would enjoy your courses more if instruction were available on mobile devices.
    a. Not at all enjoyable
    b. Slightly more enjoyable
    c. Moderately more enjoyable
    d. Very much more enjoyable
    e. Extremely enjoyable

9. Your belief that having your instruction available on a mobile device would help you stay on-track with your coursework.
    a. Not at all
    b. Slightly more on-track
    c. Moderately more on-track
    d. Very on-track
    e. Extremely on-track

10. Your belief that learning on mobile devices is the wave of the future.
    a. Not at all
    b. Maybe in five years
    c. Probably
    d. Definitely

11. Do you have any comments about learning on mobile devices that you would like to share?
    a. Open-ended

APPENDIX G

ASSESSMENTS – COMPREHENSIVE QUIZ AND SCORING AND INDIVIDUAL

MODULE QUIZZES

Comprehensive quiz
10 questions – two from each module

       Please answer all questions to the best of your ability based upon the information provided each module.

Module 1
1. Direct lightning strikes are very dangerous to humans because: (please select the best answer based upon the instruction)
    a. The person becomes part of the flash channel – 10 pt.
    b. Lighting can be hotter than the sun – 7 pt.
    c. Frequently medical assistance is not close by – 5 pt.
    d. There are more than 25 million lightning strikes per year in the U.S. – 3 pt.
    e. Because they can race along the surface of the earth – 0 pt.

2. **Transfer question** – An indirect strike can be very dangerous because:

Transfer question short answer – need to understand the why the relationship between the conductivity of the ground and other objects such as people. Answers should include concepts about:
    a. The ground stores the energy from the lightning strike
    b. The ground is a good conductor of energy
    c. The current passes along the surface of the earth to a better conductor
    d. The current is absorbed by the earth and changes the surface area from positive to negative

Module 2
1. Why might thunderstorms be less prevalent during winter months?
    a. Cool dry air sinks – 5 pt.
    b. The earth is further from the sun – 0 pt.
    c. The air is more uniformly cool and dry – 10 pt.
    d. The moisture in the air freezes and becomes snow – 3 pt.
    e. There is more static electricity – 0 pt.

2. **Transfer question** – Why does the rise of warm moist air and the fall of cool dry air create thunderstorms?

Transfer question short answer – need to understand the relationship between warm moist air and the formation of thunderstorms. Answers should include concepts about:
    a. The different air densities cause instability
    b. Lift
    c. How lift and instability create thunderstorms

Module 3
1. Ice particles play a role in the formation of lightning because:
    a. The ice particles become hail – 0 pt.
    b. The ice is a good conductor of electricity – 0 pt.
    c. The cloud mass becomes frozen – 5 pt.
    d. Ice particles carry a positive charge – 7 pt.
    e. The ice particles become both positively and negatively charged – 10 pt.
2. **Transfer question** – In a thunderstorm the upper portion of the cloud is positively charged, because?
    a. Smaller particles have a positive charge and rise to the top of the cloud

Transfer question short answer – need to understand that the smaller positively charged particles rise to the top of clouds. Answers should include concepts about:
    a. Smaller positively charged particles rise
    b. Heavier negative particles sink
    c. Ice particles can have both negative and positive charges
    d. The charges interact to create electricity

Module 4
1. Cloud-to-ground lightning primarily carries a negative charge back to earth because:
    a. The lower areas of a thunderstorm are negatively charged – 7 pt.
    b. Positive charges pool near the surface of the earth – 7 pt.
    c. It is the most dangerous form of lightning – 3 pt.
    d. Most flashes originate near the lower-negative charge center – 10 pt.
    e. It terminates with a physical object – 5 pt.

2. **Transfer question** – Lightning might strike the ground instead of a nearby tree because:

Transfer question short answer – need to understand that positive charges on the ground pool under thunderstorms and follow them around as the storm moves. Answers should include concepts about:
    a. A positive charge on the ground attracts the negative charge from the cloud
    b. Positive charges on the ground pool under thunderstorms
    c. The opposite charges are attracted to each other
    d. Even though a tall object might be nearby, the charge attraction is greater between the cloud and the ground

Module 5
1. Lightning can still be seen, even if you don't hear thunder because:
    a. Rapid heating and cooling of air near the lightning channel causes shock waves – 3 pt.

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b.   The curvature of the earth absorbs the sound – 5 pt.
c.   You are too far away to hear the thunder – 10 pt.
d.   It is possible to have thunder without lightning – 0 pt.
e.   The lightning is cloud-to-cloud lightning – 0 pt.

2.   **Transfer question** – Why would counting after you see lightning and before you hear thunder work to tell you how far away the storm is located?

Transfer question short answer – need to understand how sound and light travel. Answers should include concepts about:
   a.   Light travels faster than sound
   b.   The atmosphere can absorb some of the sound
   c.   Refraction and reflection of sound

Individual Module Quizzes

Lightning Measures

   Please answer all questions to the best of your ability based upon the information provided each module.

Module 1
1.   According to the instruction, NASA research estimates that lightning strikes ground in the United States approximately:
   a.   2,000 times per year
   b.   1.5 billion times per year
   c.   25 million times per year
   d.   50 times per year
   e.   50 times per day

2.   According to the instruction, there are _ types of lightning strikes, and they are
   a.   direct, indirect, secondary, tertiary
   b.   direct, indirect, secondary or resultant
   c.   direct and indirect
   d.   direct
   e.   flash channel and direct

3.   According to the instruction, a direct lightning strike can:
   a.   Pass right through a person without injuring them
   b.   Kill hundreds of cows with a single strike
   c.   Race along the surface of the earth
   d.   Create "branches" that jump and strike people
   e.   Won't occur if you are wearing rubber soled shoes

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4. According to the instruction, explosions, fires and accidents are most typical of:
    a. Secondary or resultant strikes
    b. Indirect strikes
    c. Direct strikes
    d. Thunderstorms
    e. Flash channels

5. **Short answer question.** If you are outside during a storm what can you do to protect yourself from a contact or side splash lightning strike? Answer should include concepts about:
    a. Moving away from trees or tall objects
    b. Move away from metal objects

Module 2
1. According to the instruction, a thunderstorm would NOT be created if:
    c. **The weather is uniformly cool and clear**
    d. The ocean currents are different temperatures
    e. Warm moist air rises
    f. Cool dry air sinks
    g. Cool air and warm air interact

2. According to the instruction, even though southern California and Florida are at a similar latitude Florida has more thunderstorms because:
    h. It is closer to the equator
    i. California is in a drought
    j. **Warm moist currents produce more moisture**
    k. More moisture is released into the air when cool air rises
    l. California has more desert which creates drier air

3. According to the instruction, unstable air masses:
    m. Are created uniformly over the earth's surface
    n. Are cool at the base and warm at the top
    o. Are created from bodies of air with uniform density
    p. **Are created when air is forced upwards or downwards**
    q. Create lift

4. According to the instruction, lift is not likely to occur:
    r. Near coastal regions
    s. **On a cool overcast day**

     t.   When pavement absorbs light
     u.   Cooler air is less dense
     v.   In summer

5. **Short answer question.** According to the instruction, what role might large paved surfaces play in the creation of storms? Answer should include concepts about:
     w.   Large paved surfaces absorbing energy from the sun
     x.   Heat from pavement creating thermal changes
     y.   Heat rising

Module 3

1. According to the instruction, lightning is formed:
     a.   When ice crystals collide within a cloud
     b.   A positive charge in a cloud interacts with a negative charge on the earth
     c.   An electrical discharge between positive and negative regions of a thunderstorm
     d.   A positive thunderstorm collides with a negative thunderstorm
     e.   Positively charged ice crystals sink to the bottom of the cloud

2. According to the instruction, on average a lightning flash:
     a.   Lasts about 3 minutes
     b.   Lasts about 3 seconds
     c.   Has no average duration
     d.   Has a single stoke per flash
     e.   Lasts about 30 microseconds

3. According to the instruction, lightning:
     a.   Is more prevalent over land in the tropics where convection is greatest
     b.   Is distributed evenly around the globe
     c.   Occurs primarily in the northern and southern hemispheres over bodies of land
     d.   Is a result of positive charges dissipating
     e.   Occurs primarily in the Arctic causing Northern Lights

4. According to the instruction, thunder:
     a.   Always accompanies lightning
     b.   Always precedes lightning
     c.   Always follows lightning
     d.   Happens 5 seconds before a lightning strike
     e.   Only accompanies lightning sometimes

5. **Short answer question** – If a cloud only has positively charged regions, why won't lightning be formed? Answer should include concepts about:
   a. It takes a positive and negative charge to create lightning
   b. Without charge interaction there is no electricity

Module 4
1. According to the instruction, the most common type of lightning is:
   a. Cloud-to-ground lighting
   b. Intra-cloud lightning
   c. Silent lightning
   d. Stratospheric lightning
   e. Positive flash lightning

2. According to the instruction, cloud-to-ground lightning primarily:
   a. Carries a negative charge back to earth
   b. Carries a positive charge back to earth
   c. Dissipates as it leaves the cloud
   d. Doesn't happen during the winter months
   e. Is a result of intra-cloud lightning overflow

3. According to the instruction, cloud-to-air lightning is caused by:
   a. Positive charges in clouds escaping to the air
   b. Positive and negative charges escaping the cloud
   c. Static electricity in the air
   d. A differential in the cloud and air temperature
   e. Opposite charged air cloud and cloud regions interacting

4. According to the instruction, a lightning strike can be as many as a billion volts in:
   a. Any situation
   b. Negative lightning strikes
   c. Positive lightning strikes
   d. Cloud-to-cloud lightning
   e. Intra-cloud lightning

5. **Short answer question** – Why do clouds appear to flicker during storms? Answer should include concepts about:
   a. Oppositely charged areas of clouds discharge within the cloud and create diffused brightening
   b. Lightning can stay within a cloud and not branch out

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Module 5
1. According to the instruction, heat lightning is:
    a. Lightning on a very hot summer day
    b. Hotter than normal lightning
    c. Thunder without lightning
    d. Lightning with no audible associated thunder
    e. Lightning seen from a far distance

2. According to the instruction, the sound of thunder:
    a. Often reflects off the earth's surface
    b. Is refracted through the stratosphere
    c. Depends upon the type of lightning
    d. Gets canceled out when sound waves bounce off the earth's surface
    e. Is loudest in storms close to the surface of the earth

3. According to the instruction, thunder can be heard:
    a. Only close to a storm
    b. Up to 50 miles away
    c. An average of 6 to 7 miles away
    d. Around the curvature of the earth
    e. About 5 seconds after a lightning strike

4. According to the instruction, thunder:
    a. When far away sounds like a low rumble
    b. When far away sounds like a quiet clap
    c. That is nearby can be almost silent
    d. Happens as a result of the temperature of lightning being about 30,000 degrees Fahrenheit
    e. If audible means that a storm has already passed

5. **Short answer question** – Sound from thunder may not always be heard because? Answer should include concepts about:
    a. The earth is curved
    b. Sound reflects and refracts through the atmosphere
    c. The movement of sound depends upon atmospheric properties

APPENDIX H

RESPONSES TO OPEN-ENDED COMMENT SECTION FROM

POST-INSTRUCTION SURVEY

Do you have any comments about learning on mobile devices that you would like to share?

1. The short clips, while informative at the time, tend to slip out of memory fairly quickly. It seems easier having reminders sent as well as doing short videos which makes the content seem to go by quickly. However, on the final quiz, while multiple choice questions were easy and simple, the short answer limit of 300 characters might be troublesome. Perhaps fill in the blanks would be better suited rather than short answers. Overall it was interesting and I look forward to seeing how this develops in the future.
2. I think it would be helpful if there were more alerts throughout the day as reminders.
3. You need headphones/ear phones to listen to the lectures. I couldn't listen to it from the phone's speakers.
4. I think videos would be more interesting to watch than the graphics and audio. I wasn't sure I had completed the module quiz correctly. I wish there was a setting to watch all the module videos continually rather than stopping and hitting play each time. Not sure I liked answering short responses on my phone. Multiple choice was better.
5. I believe that our mobile devices should be utilized for communication between Professor and student. I don't agree that learning on mobile devices is "the wave of the future" because it would be nearly impossible to limit what students can and cannot access from their personal mobile device.
6. I'm happy to have tried it out, and hope more instructors embrace it! It's nice to be able to keep up with course information when I've got a spare second, and mobile learning seems to be the way to do it.
7. The main negatives for me during this was data had to be used when my wifi was unavailable. Additionally, my phone's screen was small so I would have preferred to learn on a larger screen (visual learner).
8. BB kept shutting down and I had to log in 3 times. I did not like typing in my short responses on mobile, I'd much rather type. It's faster. I just prefer laptop-based methods.
9. Unfortunately ended up multitasking in order to participate which may have hindered my experience.
10. Depending on coursework located on BB will determine if its enjoyable.
11. I'm not sure this would be beneficial for someone studying to receive a JD. But as I did also do business in my undergraduate studies, I do believe this may have been a good alternative to classes taken on blackboard online. Very well executed and simple to follow at the ease of a mobile device.
12. It was much harder to focus on the module videos because I usually use my iPhone as a way to check out from everything. It's more of a distraction piece than a learning tool to me.
13. I felt as though having multiple modules could be a slight nuisance. Once you got into the lesson it was over. Forcing you to click out and back into another. I felt this made me lose my train of thought. I also felt that the info on the final quiz was more inquisitive than what the modules provided. While this promotes critical thinking, perhaps more in depth explications of the material could provide better retention.
14. I am very confident in my mobile skills; however, for me I'm more of a visual go to class learner. I enjoy the class setting. I found it hard to work efficiently on my phone. That's just me though. I'm sure some people are highly reliant of their phones. I'm just not like that.
15. I think I'm a little more cynical because I am a graduate student. Perhaps there is a utility for undergrads. Grad classes primarily consist of reading and discussion. We never take any tests. It's all writing. It would be horrible to have to read articles or write things on a phone.
16. The instruction provided in this study gave NO BENEFITS over accessing the same materials on any other device. The survey was very focused on the presence or absence of instruction

on a device, but what actually matters is whether that instruction makes use of any of the unique capabilities of a mobile device over a laptop or desktop. I prefer watching educational videos on my laptop because it has a larger screen, I can keep multiple videos open in difference tabs at the same time for reference, and keep a note-taking app open at the same time as the video for taking notes. My experience with mobile educational apps has been very negative. Blackboard has a horrible app, as does the eBook reader apps of most major textbook publishers. Merely "being available" on my mobile device is not enough. Instruction and materials need to make use of the strengths of mobile devices for it to be of any benefit.

17. Nice
18. I would be concerned how quizzes and tests would go. Also, note taking is a concern because taking classes through my phone would mean being on the go. I think some retention is lost when trying to learn content from a mobile device. However, it would be convenient for small assignments and mandatory readings for class to use my device.
19. The videos did not load for me on the first or second day using ASU wifi, my home wifi, or my mobile data. I did not answer the quizzes because of this.
20. It would be nice that if we are learning on mobile devices if all other sounds and notifications on our phones would be silent. I know that while watching the videos, my email would sing which would lower the volume on the instructional video.
21. The short less than a minute lectures was bothersome to me. Combined for one unit hey may have made a two-minute lecture. And I think I'd have preferred to just watch the one. Although, I understand it may have been easier for phones to handle.
22. A notification when a new module or quiz is available would be helpful for staying on track.
23. Have calls, emails, and all other app notifications come us while trying to complete the modules was distracting and not conducive to learning
24. Even though they are small, the videos take long time to load, making video watching undesirable.
25. Some of the module quiz answer choices were confusing.
26. The interface in the Blackboard app is terrible-- just look at the app reviews.
27. Learning on mobile device was fascinating. However, I faced 1 problem that even on a broadband connection the videos took a lot of time to buffer. I had to wait for the buffering a lot and that is why I was not able read the module 5
28. Maybe combining modules....or having less
29. It makes life easy and reduces on the stress of both the professors and the students.
30. I need alerts and reminders. Also, this app needs an update. Increase the resolution and make it easier to respond
31. It's pretty interesting and can be convenient but maybe later on in the future
32. Mobile software used was glitchy (would freeze after every quiz). I did not feel as focused because I am not used to have to use my phone to complete assignments, so it did not feel as important, but I could overcome this with some time and practice I believe. Overall it was interesting to experience this as I believe teaching and courses are going in this direction.
33. I think mobile devices would be a great tool to receive brief lectures, maybe review sessions. However, I don't really think they would be effective in learning in-depth, technical subjects. Perhaps adjusting the ways in which the material is presented may be beneficial
34. I feel like it would be more of a benefit if the questions were just multiple choice or true false so that you don't have to wait for the instructor to grade your answers and you can get them right away
35. Without using many push notifications to keep user aware I find this new use of mobile technology would be limited and cumbersome.
36. I had an issue with the final quiz. Once I had completed it, the app went black and I couldn't tell whether it submitted or not.

37. It might be that the voice in these modules was very monotone, but I don't believe we should be learning from our mobile devices just because it took a while for me to learn because I was too comfortable and that wouldn't happen in a classroom setting
38. I didn't learn much because my natural tendency while on my phone is to multitasking and only give it half the amount of attention that I should give.
39. Mobile device education is the future of the academics. It should be encouraged.
40. My primary issue is Blackboard's software, which is generally bad, and the lesson not utilizing the uniquely useful features of a phone (e.g. touchscreen can be much more intuitive for spatial reasoning, so using a phone would be excellent for high school geometry, but not necessarily calculus). The lightning lessons were all videos which would be more convenient to watch on my computer anyways.
41. Having more notes on the lecture slides would have assisted me.
42. Sometimes you are easily distracted while watching these videos on the mobile device, maybe due to a mail or other application's notifications. this distracts the students.
43. Love it
44. I am totally fine with online instruction. I think it can be really flexible and convenient. However, after this study I think I would prefer to just stick with my laptop. I have a much better laptop than my phone so I prefer working on there. Using the phone proved to be much slower and not as intuitive. The Blackboard was slow and somethings were hard to access.
45. THANK YOU!
46. I feel that the learning experience wasn't terrible but it I wish the learning was more engaging. I understand that there are limitations when it comes to the Blackboard however I wish there was more engagement with the videos. Maybe some animation for the info graphics portions of the videos. I also wish that there were tittle slides to differentiate the lessons. Everything seemed to be matching but that can get confusing if a user is wanting to go back and review as previous lesson.
47. For this project, I couldn't figure out why my sound wasn't working, turns out you need to turn on your notification sounds to hear it (Won't work on mute), might want to let users know this in the instructions!
48. There were several questions that I had some difficulty understanding and answering properly.
49. The inability to multitask or take notes during the lectures was unhelpful and the course material was viewable – I could hear the lectures but I couldn't see the graphics or what they were saying, which was very unhelpful.

APPENDIX I

INSTITUTIONAL REVIEW BOARD CONSENT

EXEMPTION GRANTED

Robert Atkinson
Computing, Informatics and Decision Systems Engineering, School of (CIDSE)
480/727-7765
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Dear Robert Atkinson:

On 2/16/2016 the ASU IRB reviewed the following protocol:

Type of Review:	Initial Study
Title:	Microlearning with Mobile Devices: Effects of Distributed Presentation and the Testing Effect
Investigator:	Robert Atkinson
IRB ID:	STUDY00003713
Funding:	None
Grant Title:	None
Grant ID:	None
Documents Reviewed:	• Recruitment email revised-2-10-16, Category: Recruitment Materials; • Study Surveys, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Study Quizes, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • 503 revised 2-10-16, Category: IRB Protocol; • Study Comprehensive Quiz, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Microlearning consent revised 2-10-16, Category: Consent Form;

The IRB determined that the protocol is considered exempt pursuant to Federal Regulations 45CFR46 (2) Tests, surveys, interviews, or observation on 2/16/2016.